SCIENTIFIC AGRICULTURE

VOLUME 25 OCTOBER, 1944 No. 2

INCREASE IN PRODUCTION AND VALUE OF THE WHEAT CROP IN MANITOBA AND EASTERN SASKATCHEWAN AS A RESULT OF THE INTRODUCTION OF RUST RESISTANT WHEAT VARIETIES[1]

J. H. CRAIGIE[2]

Dominion Laboratory of Plant Pathology, Winnipeg, Manitoba

[Received for publication July 28, 1944]

INTRODUCTION

Does scientific research pay? In industry, this question has been answered very definitely in the affirmative. In agriculture, the same positive answer can be given by a great many farmers and others who have directly benefited from agricultural research. Probably if the public in general were more aware of the increase in the national income that may, and does, accrue from agricultural research, there would be a more insistent demand that ample financial support be provided for it. Broadly speaking, the prosecution of agricultural research is dependent on government support, and the support a government can provide for it is, in turn, largely dependent on the insistence of the public for such research and on the willingness of the taxpayers to supply funds for it. This insistence and willingness, in turn, will probably be directly proportional to the economic benefit that may accrue from the research, or rather in direct proportion to the awareness of the public in respect to that benefit.

In Canada, a large number of research projects in agriculture are now under way, but all, or practically all, of them are constantly hampered to a greater or less extent through lack of adequate financial support. There seems, therefore, to be an urgent need of bringing to the attention of the Canadian people concrete evidence of the benefit that has already accrued to them through agricultural research. The present paper gives such evidence in respect to one particular line of research, namely, the development of wheat varieties resistant to stem rust. In it, an estimate is given of the extent to which the general distribution of such varieties in Manitoba and eastern Saskatchewan, the "rust area" of Western Canada, has increased in these areas wheat production and, as a consequence, farm income.

Occurrence of Stem Rust

Previous to the distribution of rust resistant wheats in Manitoba and eastern Saskatchewan, stem rust, as has just been implied, was always more destructive in these two areas than in western Saskatchewan and in Alberta, although, in the latter areas, it caused a greater or less amount of damage in occasional years. It is known to have been present in Manitoba as

[1] Contribution No. 796 from the Division of Botany and Plant Pathology, Science Service, Dominion Department of Agriculture, Ottawa, Canada.
[2] Officer-in-Charge.

early as 1891, and probably was present considerably earlier. It did considerable damage, at least in Manitoba, in 1896, as it did also in 1902 and in 1903. It was epidemic in Manitoba and eastern Saskatchewan in 1904, and moderately severe in 1905. A heavy attack developed in parts of these two areas in 1911 and infection was prevalent in 1914. An epidemic of severe intensity broke out in 1916, and others followed in 1923, 1927, and 1935, and in 1938 (wherever rust resistant varieties were not grown). Attacks little short of epidemic intensity occurred in 1919, 1921, 1925, and 1930. In 1937, stem rust was of moderate to severe intensity in Manitoba, except along the western margin of the province where—as well as in the greater part of Saskatchewan—severe drought conditions caused a complete crop failure. In the remaining years from 1900 onward to 1939, the first year in which varieties of wheat resistant to stem rust were widely grown throughout the "rust area" of Western Canada, the severity of infection varied from light to moderate. Had not rust resistant wheat varieties been distributed in this area (and in the northern Mississippi Valley as well), it is probable that stem rust would have continued to recur and be as destructive there as it formerly had been.

Figure 1 indicates the approximate western boundary of severe stem rust damage in 1935 and 1938. In 1916 and 1927, the area of severe damage extended somewhat further westward than in 1935 or 1938; in 1923, it did not extend as far as in either of these years. That is to say, the area severely affected by stem rust varied considerably in size from one epidemic year to another.

Losses from Stem Rust

The bulk of the loss from stem rust in Western Canada has occurred in Manitoba and eastern Saskatchewan, although substantial loss has occurred in occasional years in western Saskatchewan and Alberta. The loss from stem rust in wheat, to say nothing of the loss in oats and in barley, has been enormous. It is generally agreed that in 1916 the loss in wheat in Western Canada amounted to 100,000,000 bushels (2, 3). In 1927, it was calculated to be about 90,000,000 and in 1935, over 87,000,000 bushels (4). For the 11-year period 1925-1935, the average annual loss in Manitoba and Saskatchewan was calculated to be 35,518,000 bushels, constituting a cash loss through reduction in yield alone of $30,784,000 each year of this period (4).

Not only does stem rust greatly reduce production, but it also causes a pronounced reduction in the quality, and hence in the grade, of the grain, which reduction, in turn, is reflected in a reduced market price. The rusted wheat crop of 1916 may be taken to illustrate these two sources of loss. On the supposition that no loss from stem rust had occurred in that year, an additional 100,000,000 bushels of wheat would have been available for consumption. It is fair to assume that practically all of this wheat would have fallen within the grades No. 1 to No. 4 Northern. From October, 1916, to March, 1917—during which period most of the grain would have

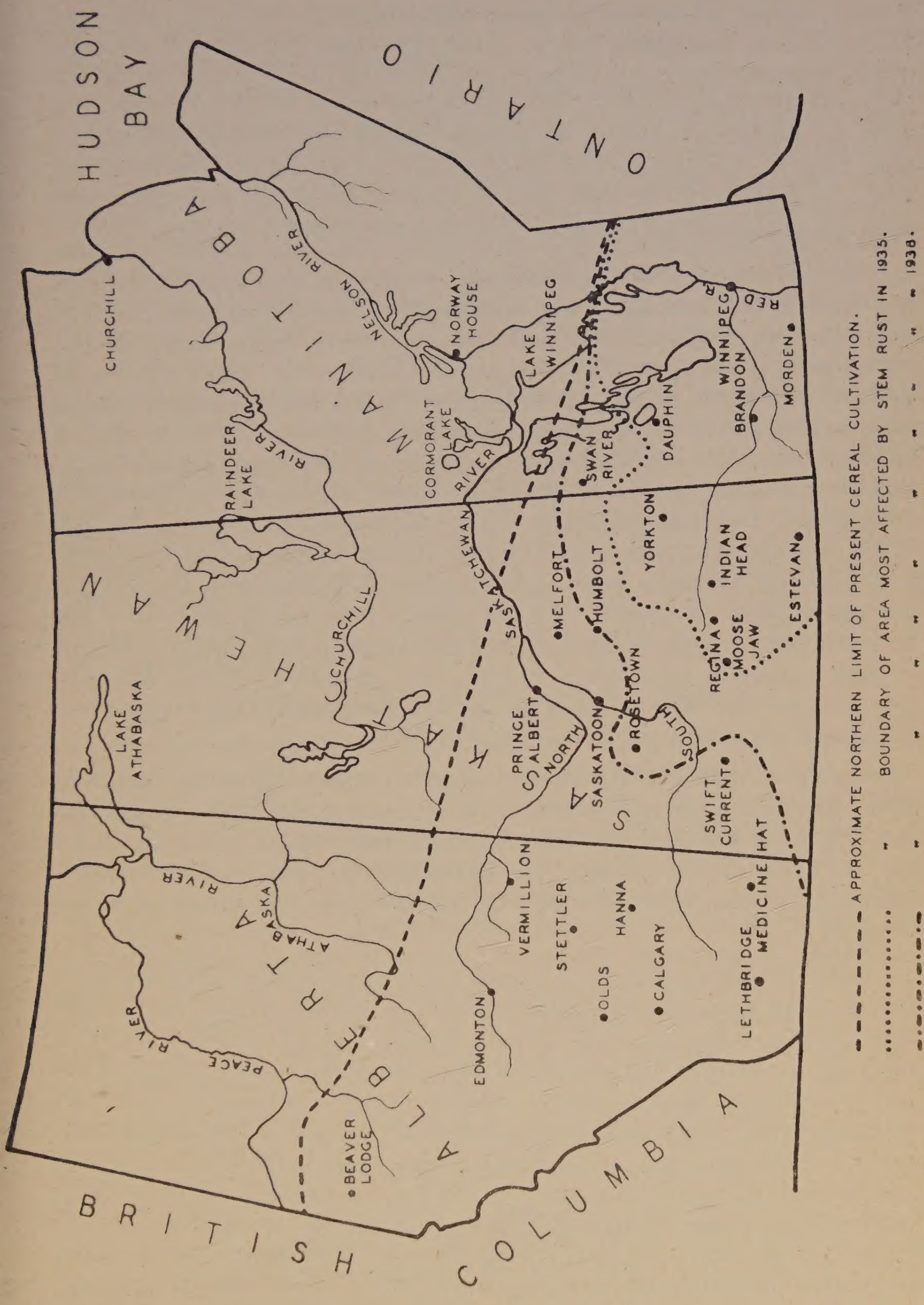


FIGURE 1. Map of Western Canada, showing the approximate boundary of the area most affected by stem rust in 1935 and 1938.

probably been sold off the farm—the average price at Winnipeg, Man., for these grades of wheat were, respectively, about $1.75, $1.72, $1.70, and $1.59 (Canada Year Book, 1918). In the following four months, the price of wheat soared very much higher; only in one of these months (April) did the monthly average for No. 4 Northern fall below $2.00 per bushel. If $1.70 per bushel be taken as the average price for the 100,000,000 bushels that were not produced, it is evident that the monetary loss from this source was $170,000,000, although, in view of the higher price prevailing after March, the actual loss may have been considerably higher.

To this loss there must be added the loss due to reduction in grade of the wheat that was produced. As, in 1916, the damage from stem rust was not pronounced in Alberta, it may be assumed that the loss due to reduction in grade occurred entirely in Manitoba and Saskatchewan. In that year, the wheat production in Manitoba amounted to about 27,400,000 and, in Saskatchewan, to about 121,800,000 bushels, making a total of approximately 149,200,000 bushels. Again, on the supposition that no stem rust damage had occurred and that most of this wheat would have fallen within the grades No. 1, 2, 3, or 4 Northern, the value of the crop would have been (at $1.70 per bushel) in the vicinity of $253,640,000. Owing to the reduction in the grade of the grain, however, the average price per bushel received for the Manitoba wheat was $1.23 and for the Saskatchewan wheat, $1.28 per bushel. It can readily be calculated, therefore, that the actual farm income from the wheat crop in these two provinces was $189,606,000. Thus the loss due to reduction in grade was $253,640,000 less $189,606,000, or $64,034,000.

Owing therefore to the ravages of stem rust in Western Canada in 1916, there was a loss of $170,000,000 from reduction in wheat production and of $64,034,000 from reduction in grade, thus making a total monetary loss of $234,034,000. Bailey (1) estimated the loss at $200,000,000. According to the above calculation, his estimate was sufficiently conservative.

Although, in the foregoing paragraphs, the discussion is confined to damage from stem rust of wheat, it should be mentioned that leaf rust of wheat has been present every year in Western Canada and in occasional years did considerable damage, especially in Manitoba and the more easterly portion of Saskatchewan. Before varieties of wheat resistant to stem rust were distributed, the preponderant amount of rust damage was unquestionably caused by stem rust. The distribution of these varieties has, however, only partially eliminated damage from leaf rust, as, of the four rust resistant varieties now grown (Thatcher[3], Regent, Renown, and Apex), only two are resistant to leaf rust. In fact, the variety most widely grown in Manitoba and eastern Saskatchewan is highly susceptible to this rust. If all of the four rust resistant varieties now grown were resistant to leaf rust as well

[3] A variety developed by Dr. H. K. Hayes of the University of Minnesota, U.S.A.

as to stem rust, the increase in wheat production brought about by the distribution of them in Manitoba and eastern Saskatchewan would be slightly greater than that indicated subsequently in this paper.

Rust Resistant Wheats Distributed

The distribution of rust resistant wheats was begun on a small scale in Manitoba in 1936, and by 1938 slightly more than one-half of the wheat acreage in this province was sown to such wheats. In the latter year, approximately 30% of the wheat acreage was sown to durum wheat varieties. As the durum wheats grown are partially resistant to stem rust, the year 1938 may be taken as the first year in which resistant varieties were widely grown in Manitoba. (In passing, it may be mentioned that, had it not been for the rapid increase in durum production after the epidemic of 1923, the loss from stem rust in Manitoba from that year to 1937 would have been much greater than indicated in this paper). As mentioned earlier, stem rust was epidemic in 1938 on susceptible wheats in Manitoba as well as in eastern Saskatchewan, and much heavier infection than usual was present in western Saskatchewan and in Alberta. Owing to a scarcity of seed of the resistant varieties, distribution of them in eastern Saskatchewan was somewhat less rapid than in Manitoba, so that it was not until 1939 that rust resistant varieties became widely grown in that area. The years 1938 and 1939 may, therefore, be regarded, respectively, as the first years in which the growing of rust resistant wheats definitely influenced wheat production in Manitoba and eastern Saskatchewan.

COMPARISON OF THE YIELD OF MARQUIS WHEAT AND FOUR RUST RESISTANT WHEATS IN THE PRESENCE OF RUST

By way of illustrating the superiority in yielding ability, in the presence of rust attack, of the rust resistant wheats now being widely grown in the "rust area" of Western Canada over rust susceptible wheats that were formerly grown in this area, data are given in Table 1 on the yield of Thatcher, Regent, Renown, and Apex, four rust resistant varieties, and of Marquis, a rust susceptible variety formerly very extensively grown in this area. These data are taken from the Co-operative Test Reports of the Sub-Committee on Plant Breeding, Associate Committee on Field Crop Diseases, National Research Council and Dominion Department of Agriculture, and are based on the yields of adequately replicated rod rows grown at four Stations in Manitoba in 1935, 1938, and 1940. On susceptible varieties, rust was extremely severe in 1935, severe to moderately severe in 1938, and comparatively light in 1940. In each of these years, the severity of infection varied somewhat from Station to Station, the infection being regularly more severe at Winnipeg, where the naturally-occurring infection was intensified by an artificially-induced infection. In respect to plant growth, Marquis as well as Thatcher, Regent, and Renown are well adapted to Manitoba conditions. Apex, on the other hand, is not generally so well adapted to these conditions as are the other four varieties, a fact that largely accounts for its yield being usually somewhat lower than that of the other three resistant varieties.

TABLE 1.—COMPARISON OF THE EFFECT OF RUST ON THE YIELD PER ACRE OF THE WHEAT VARIETIES MARQUIS, THATCHER, RENOWN, REGENT, AND APEX AT FOUR STATIONS IN MANITOBA IN 1935, 1938, AND 1940

(Based on the yield of replicated rod row plots)

Stations	Wheat varieties				
	Marquis	Thatcher	Regent	Renown	Apex
	bu.	bu.	bu.	bu.	bu.
1935					
Morden	5.5	32.9	27.4	21.9	17.5
Winnipeg	1.9	21.8	21.1	21.2	12.3
Brandon	8.8	43.5	40.3	37.8	30.2
Gilbert Plains	1.7	26.5	30.7	25.6	18.4
Average	4.5	31.2	29.9	26.6	19.6
1938					
Morden	17.6	30.4	38.4	33.0	32.8
Winnipeg	5.0	18.1	25.7	20.2	17.6
Brandon	15.6	45.7	48.9	47.5	44.6
Gilbert Plains	21.2	30.8	30.5	32.4	30.0
Average	14.8	31.2	35.9	33.3	31.2
1940					
Morden	23.7	44.5	45.6	41.1	39.4
Winnipeg	12.7	43.4	41.0	42.4	34.0
Brandon	32.5	39.1	40.2	37.8	37.9
Gilbert Plains	40.3	37.3	37.3	31.7	33.3
Average	27.3	41.1	41.0	38.2	36.1

It is evident from Table 1 that, in 1935, the average yield of Marquis was extremely low, whereas that of the resistant varieties was from 4 to 7 times higher. In 1938, owing to the comparatively late date at which rust became severe on susceptible wheats in Manitoba, the damage to such varieties was considerably less pronounced than in 1935. Despite this ameliorative circumstance, the average yield of the resistant varieties was more than double that of Marquis. Even in 1940, a relatively light rust year, the resistant varieties out-yielded Marquis, except at Gilbert Plains, by a considerable amount. The marked disparity between the yield of these varieties and that of Marquis in 1935 and 1938, and at Winnipeg and Morden in 1940, is almost entirely attributable to injury suffered by Marquis from rust. In the absence of rust injury, Marquis would have approximated the resistant varieties in respect to yield, or even might have occasionally surpassed them, as it did at Gilbert Plains in 1940. Consequently, over a period of years in which wide variation from season to season occurred in the amount of injury caused by rust, the disparity between the average yield of rust susceptible and rust resistant wheats has been much less pronounced than that just indicated.

IMPROVEMENT IN WHEAT PRODUCTION AND VALUE RESULTING FROM THE GROWING OF RUST RESISTANT VARIETIES

In order to gain some idea of what economic benefit rust resistant wheats have been to wheat producers in Manitoba and eastern Saskatchewan—and indirectly to everyone in Canada—a comparison may be made of the actual wheat production in these two areas during the years in

which rust resistant varieties were widely grown, and what the production in these two areas would probably have been during the same years if rust resistant varieties had not been grown. The difference between the actual production (when rust resistant varieties were grown) and the probable production (had such varieties not been grown) will indicate, for each area, the increase in production that has accrued as a result of the introduction of rust resistant wheats. From this difference, the monetary improvement in farm income arising from the increased production can be calculated. The computation, of course, disregards entirely the improvement in yield and value of the wheat crop in other parts of Canada where rust resistant varieties have been introduced.

Attention should be directed to the fact that the improvement in wheat production resulting from the growing of rust resistant wheats is largely, but not entirely, attributable to the control of stem rust effected by these wheats. It is known that, even in the absence of stem rust, the rust resistant varieties tend to out-yield Marquis wheat, the variety most widely grown in Western Canada prior to the introduction of rust resistant ones. In the following computations, no attempt has been made to differentiate between the increased production attributable to this factor and that attributable to the control of stem rust, as both sources of increase are directly attributable to the development and distribution of rust resistant wheats.

The data relative to acreage, actual production and actual value for Manitoba and eastern Saskatchewan, as well as the data on which the probable production is based, were taken, respectively, from the annual crop report bulletins of the Manitoba Department of Agriculture and the annual reports of the Saskatchewan Department of Agriculture. From these two sources and The Canada Year Book were taken the data relative to price per bushel.

Improvement in Manitoba.

A comparison is given in Table 2 of the actual wheat production in Manitoba during the 6 years 1938 to 1943—the period in which varieties of wheat resistant to stem rust were largely grown—and the probable production (had susceptible varieties continued to be grown). The probable production in each of these years is based on the acreage sown to wheat in each of the 6 years and the average yield per acre for 16 previous years, namely, 1916-1928, 1930, 1935, and 1937. The years 1929, 1931-1934, and 1936 are omitted, because, in these years, pronounced drought in some parts of the province markedly reduced the yield. The omission of these years helps to eliminate drought as a factor influencing the average yield per acre. Although during the period 1917 to 1921, drought or partial drought conditions prevailed in some parts of the province, any influence that these conditions may have on this average is probably more than sufficiently off-set by similar conditions in parts of the province in the years 1939, 1940, and 1941.

TABLE 2.—COMPARISON OF (A) THE ACTUAL WHEAT PRODUCTION (WHEN RUST RESISTANT VARIETIES WERE GROWN) AND (B) THE PROBABLE WHEAT PRODUCTION (IF RUST RESISTANT VARIETIES HAD NOT BEEN GROWN) IN MANITOBA DURING THE 6-YEAR PERIOD 1938-1943

Year	Total acreage sown	A	B		Difference in production
		Actual production	Probable yield per acre[1]	Probable production	
	(000)	(bu.) (000)	(bu.)	(bu.) (000)	(bu.) (000)
1938	3,184	50,000	15.15	48,253	1,747
1939	3,201	61,300	15.15	48,495	12,805
1940	3,512	66,400	15.15	53,206	13,194
1941	2,442	51,000	15.15	36,996	14,004
1942	1,930	53,650	15.15	29,239	24,411
1943	1,640	41,000	—	24,846	16,154
Total	15,909	323,350	—	241,035	82,315
6-year average	2,651	53,891	—	40,172	13,719

[1] Average yield for the 16 years 1916-1928, 1930, 1935, and 1937.

The difference, therefore, between the actual production of wheat in the province during the 6 years 1938-1943, in which varieties of wheat resistant to stem rust were largely grown, and the production that would have probably been obtained if susceptible varieties had continued to be grown in these years, may logically be attributed to the growing of rust resistant varieties of wheat. It will be seen in Table 2 that this difference in wheat production for the 6-year period amounts to 82,315,000 bushels, or to an annual average difference of 13,719,000 bushels. The average annual wheat acreage in Manitoba was 2,651,000 acres, so that the average difference in yield per acre between the actual production and the probable production is 5.17 bushels.

This increase in wheat production has very materially improved farm income in this province. Table 3 gives the actual value of the wheat crop in these 6 years and the probable value of that crop if rust resistant wheat varieties had not been grown. The probable value given is very likely somewhat higher than it should be, as it is based on the price per bushel obtained in each respective year for Manitoba-produced wheat that was not damaged by rust. If rust resistant wheats had not been grown, there would have probably been considerable rust damage in some of these 6 years, and consequently, owing to a lowering of the grade in any such year, the average price per bushel would have been somewhat less than that given in this table. On the basis of the average price per bushel, the difference between the two values is $57,505,000, or an annual difference of $9,584,000. In other words, the farm income of Manitoba was increased by this amount n each of the 6 years.

TABLE 3.—COMPARISON OF (A) THE ACTUAL VALUE OF THE WHEAT CROP (WHEN RUST RESISTANT VARIETIES WERE GROWN) AND (B) THE PROBABLE VALUE OF THE CROP (IF RUST RESISTANT VARIETIES HAD NOT BEEN GROWN) IN MANITOBA DURING THE 6-YEAR PERIOD 1938-1943

Year	Average price per bushel	A	B		Difference in value
		Actual value	Probable production	Probable value	
		(000)	(bu.) (000)	(000)	(000)
1938	$0.61	$30,500	48,253	$29,434	$ 1,066
1939	0.55	33,715	48,495	26,272	7,443
1940	0.53	35,192	53,206	28,199	6,993
1941	0.51	26,010	36,996	18,868	7,142
1942	0.72	38,628	29,239	21,052	17,576
1943	1.07	43,870	24,846	26,585	17,285
Total	—	207,915	—	150,410	57,505
6-year average	—	34,652	—	25,068	9,584

Perhaps it would be of interest to gain an idea of how much loss this province suffered in wheat production and in farm income through the lack of suitable rust resistant wheat varieties during the 16 years referred to above. It is realized that, during these years, an increased production would have probably lowered the price of wheat, but any fall in the price of wheat as a result of higher production in these years would have been largely off-set by a fall in price due to loss of grade resulting from damage by rust. The total acreage sown to wheat in these years was 43,707,100 acres, and it has been shown above that the rust resistant wheats out-yielded susceptible wheats by 5.17 bushels per acre. Had resistant wheats been grown during these 16 years, they would have probably out-yielded the susceptible wheats by an equal amount per acre. The total loss in these 16 years was, therefore, probably in the vicinity of 225,965,000 bushels, or an average annual loss of approximately 14,123,000 bushels. The average price of Manitoba-produced wheat for these years was approximately $1.19 per bushel, so that the total monetary loss was about $268,898,000, or an annual loss of $16,806,000.

Improvement in Eastern Saskatchewan

As pointed out earlier, stem rust has usually been somewhat less destructive in eastern Saskatchewan than in Manitoba, but the total acreage of wheat is very much greater in the former than in the latter area, and hence, over a period of years, the aggregate loss in production and value of the crop through damage from stem rust would be expected to be greater. For the purpose of the present computation, eastern Saskatchewan is taken to include the following six crop districts: No. 1 (South-Eastern), No. 2 (Weyburn-Regina), No. 3 (South-Central), No. 5 (East-Central), No. 6 (Central), and No. 8 (North-Eastern). Actually, only the

eastern half of No. 3 and of No. 6 lie within the "rust area", but, as production data for these two halves are not available, it is necessary to regard both districts as lying wholly within that area.

In Table 4 is given a comparison of the total actual wheat production in eastern Saskatchewan during the 5-year period 1939-1943—a period during which rust resistant varieties of wheat were extensively grown—and the total probable wheat production in these years if rust resistant varieties had not been grown. The data are given by crop districts, but to conserve space, only the totals for the 5 years are presented. The total probable production in any given district is calculated from the total acreage sown to wheat in that district during the 5 years and the average yield per acre obtained in that district during 16 years (1916-1928, 1930, 1935, and 1938) in which rust susceptible varieties were largely grown. (Drought caused a complete crop failure in eastern Saskatchewan in 1937, and hence the substitution of 1938 for 1937, although in 1938 probably about one-quarter of this area was sown to rust resistant wheats). Table 4 shows that, for the six crop districts, the total actual wheat production exceeds the total probable wheat production by 138,101,000 bushels. In other words, the growing of rust resistant wheats in these 5 years increased the total production by that amount, or by an average of 27,620,000 bushels per year.

TABLE 4.—COMPARISON OF (A) THE TOTAL WHEAT PRODUCTION (WHEN RUST RESISTANT VARIETIES WERE GROWN) AND (B) THE TOTAL PROBABLE WHEAT PRODUCTION (IF RUST RESISTANT VARIETIES HAD NOT BEEN GROWN) IN SIX CROP DISTRICTS IN EASTERN SASKATCHEWAN DURING THE 5-YEAR PERIOD 1939-1943

Crop District	Total acreage sown	A	B		Difference in production
		Actual production	Probable yield per acre[1]	Probable production	
	(000)	(bu.) (000)	(bu.)	(bu.) (000)	(000)
No. 1	3,707	67,643	13.80	51,104	16,539
No. 2	7,306	123,396	14.72	107,544	15,852
No. 3	14,899	255,220	14.74	219,611	35,609
No. 5	5,977	124,797	17.20	102,804	21,993
No. 6	10,013	170,305	14.04	140,583	29,722
No. 8	3,951	94,917	19.37	76,531	18,386
Total	45,853	836,290	—	698,177	138,101
5-year average	9,170	167,258	—	139,635	27,620

[1] Average yield per acre for the 16 years 1916-1928, 1930, 1935, and 1938 in the respective crop districts.

The improvement in farm income in eastern Saskatchewan resulting from the introduction of rust resistant wheats is indicated in Table 5. This table gives, for each of the 5 years, the actual value of the wheat produced in the six crop districts, and the probable value of the wheat that would have been produced in them if rust susceptible varieties had continued to be grown during these 5 years. The price per bushel in any given year is the average price per bushel obtained in that year for wheat pro-

duced in Saskatchewan as a whole. As pointed out earlier in connection with a similar computation for Manitoba, the probable value is very likely over-estimated, for, if rust susceptible varieties had been grown, the price per bushel received, owing to a reduction in the grade of the wheat, would probably have been somewhat less in some of the years than that indicated. According to these calculations, the actual value of the wheat produced during the 5 years is $88,293,000 in excess of the probable value for these years. In other words, the farm income in eastern Saskatchewan was increased on an average by $17,658,000 each year.

TABLE 5.—COMPARISON OF (A) THE ACTUAL VALUE OF THE WHEAT CROP (WHEN RUST RESISTANT VARIETIES WERE GROWN) AND (B) THE PROBABLE VALUE OF THE CROP (IF RUST RESISTANT WHEAT VARIETIES HAD NOT BEEN GROWN) IN SIX CROP DISTRICTS OF EASTERN SASKATCHEWAN DURING THE 5-YEAR PERIOD 1939-1943

Year	Average price per bushel	A	B		Difference in value
		Actual value	Probable production	Probable value	
		(000)	(bu.) (000)	(000)	(000)
1939	$0.54	$100,122	152,221	$82,119	$18,003
1940	0.53	92,538	166,078	88,021	4,517
1941	0.53	56,498	130,975	69,417	(−) 12,919
1942	0.65	157,521	135,399	88,009	69,512
1943	1.03	131,159	118,427	121,979	9,180
Total	—	537,838	—	449,545	88,293
5-year average	—	107,567	—	89,909	17,658

During the 16 years 1916-1928, 1930, 1935, and 1938, eastern Saskatchewan sustained a pronounced monetary loss through the lack of suitable rust resistant varieties of wheat. An estimate of what this loss has been can be arrived at by a simple calculation. In Table 4 it is shown that, for the 5-year period, the average annual acreage sown was 9,170,000 acres and the average annual difference between the actual production and the probable production was 27,620,000 bushels. It is evident, therefore, that rust resistant wheats yielded on an average 3.0 bushels more per acre than susceptible wheats would have yielded had they been grown. The total wheat acreage in the six crop districts for the 16 years was 143,351,000 acres. On the supposition that rust resistant varieties had been grown during these 16 years, the production of wheat would have been increased by 430,053,000 bushels, or approximately 26,878,000 bushels each year. That is to say, there was an annual loss in wheat production equal to this amount. For these 16 years, the average price of wheat produced in Saskatchewan was $1.14 per bushel—a much higher average price than prevailed from 1939 to 1943—so that, for these 16 years, the total loss was somewhere about $490,260,000, or a loss of $30,641,000 each year.

DISCUSSION

It is evident from the foregoing discussion that the development of rust resistant wheats and their general introduction in the bad rust area of Western Canada has been of immense financial benefit to wheat growers in that area, and indirectly in greater or less degree to everyone in Canada. Such varieties have also been introduced in other parts of Canada, and, to the extent that stem rust has been destructive in those parts, to that extent has the value of the wheat crop in those parts been increased.

Not only has the development of rust resistant wheats been of immense financial benefit to everyone concerned, but it has been of decided benefit to the morale of the farmers themselves and of the public in general. It has removed one of the worst wheat crop hazards. The farmer now has confidence, that, barring insect damage, and drought, hail, or other crop hazard over which he has no control, a crop will reward his labours. The public is assured of an adequate wheat supply and of more stable economic conditions.

Furthermore, there seems to be good evidence that similar benefits, even if less pronounced, have accrued in respect to the production of barley in Western Canada, particularly in the "rust area." Wheat stem rust attacks barley as well as wheat, that is to say, it attacks susceptible varieties of both crops. The extensive growing of rust resistant wheats in Manitoba and eastern Saskatchewan (and in the northern Mississippi Valley as well) has enormously reduced the amount of stem rust inoculum (red spores) available for the spread of stem rust from wheat to barley. As a result of this decrease in the amount of inoculum, a great deal less infection than formerly has developed in the last four or five years on barley, especially on late sown barley. This circumstance, in turn, has improved the income of barley growers in this area, and, thereby, has improved the national income. Unfortunately, however, the danger of rust damage to barley has not been entirely removed. To overcome this danger completely, rust resistant varieties of barley must be developed.

As, under ordinary field conditions, wheat stem rust does not attack oats, the growing of rust resistant wheats has not had a corresponding effect on the amount of stem rust infection on oats. In this connection, it may be said that oat varieties highly resistant to the races of oat stem rust that have in past years been prevalent in Canada, have been produced and are now rather widely distributed. The improvement in farm income from this source itself has been substantial.

In comparison with the loss that formerly occurred from damage to wheat by stem rust, the cost of rust research in Canada has been so small that it is scarcely worthy of mention. It is safe to say that from 1916—prior to that apparently nothing was spent—up to the present, the total amount expended in Canada by governments, institutions, and other organizations, all combined, did not exceed \$2,000,000. In fact, the amount was probably a good deal less. The present computations show that the development and introduction of rust resistant wheats have increased the average annual value of the wheat crop in Manitoba and eastern Saskatchewan, respectively, \$9,584,000 and \$17,658,000, or a combined increase

of $27,242,000. In other words, since the advent of rust resistant wheats, the improvement in farm income in these two areas would, on an average, repay in a single year more than thirteen times over all the expenditure ever made by Canada on wheat rust research. (If the average price per bushel had been as high for wheat during the last 5 years as it was in the 16 earlier years discussed in this paper, the annual improvement in farm income would have repaid the expenditure on wheat rust research more than twenty-three times over).

As indicated in the introduction, the scope of this paper is strictly limited, and no digression into a general discussion of the advantages that have accrued already, or may accrue in future, from other lines of scientific agricultural research is admissible here. One point, however, may be mentioned. If Canada is to maintain a high export level of farm products, and particularly if she must continute to compete in respect to these products in world markets, it is absolutely essential that production costs of farm products in Canada be reduced. To accomplish this, the productive capacity of the various factors involved in farm production must be increased. There is little question that this can be accomplished through concentrated scientific research, and through it alone can it be accomplished at minimum cost.

SUMMARY

An estimate is given of the increase in wheat production and of the resulting increase in farm income from this source that have accrued through the development and introduction of wheat varieties resistant to stem rust. It is shown that, in Manitoba for the 6-year period 1938-1943, the actual average annual production and value of the wheat crop exceeded the probable average annual production and value—had rust susceptible varieties continued to be grown during these years—by 13,719,000 bushels and $9,584,000, respectively. In eastern Saskatchewan, for the 5-year period 1939-1943, the corresponding figures are 27,620,000 bushels and $17,658,000. That is to say, the growing of rust resistant wheat varieties in these two areas has increased, respectively, the average annual wheat production and farm income in the "rust area" of Western Canada by 41,339,000 bushels and $27,242,000.

It is estimated that, if the present rust resistant varieties of wheat had been grown in Manitoba in the 16 years 1916-1928, 1930, 1935, and 1937, the yield per acre would have exceeded that obtained from the rust susceptible varieties that were grown in those years by 5.17 bushels. In other words, the average annual loss in wheat production for these 16 years was about 14,123,000 bushels, and in farm income, $16,806,000. Similarly, in eastern Saskatchewan, if the present rust resistant varieties had been grown in the 16 years 1916-28, 1930, 1935, and 1938, the average yield per acre would have been increased by 3.0 bushels, with a consequent annual increase in wheat production of 26,878,000 bushels, and in farm income

of \$30,641,000. The total annual monetary loss in the "rust area" of Western Canada for these 16 years was, therefore, in the neighbourhood of \$47,447,000.

Furthermore, it is estimated that, in the 5-year period 1939-1943, the average annual increase (\$27,242,000) in farm income accruing from the growing of rust resistant wheats in Manitoba and eastern Saskatchewan would repay more than thirteen times over the total expenditure made by Canada on wheat rust research.

REFERENCES

1. Bailey, D. L. Studies in cereal diseases. IV. Stem rust in Western Canada. Dom. Dept. of Agric. Bull. 106-N.S. 1928.
2. Buller, A. H. R. Essays on wheat, pp. 1-339. The McMillan Company, New York. 1919.
3. Fraser, W. P. The outbreak of wheat rust in 1916. Month. Bull. Agric. Statist. Dept. Trade and Commerce, Ottawa, Canada, 11 : 61-67. 1918.
4. Greaney, F. J. Cereal rust losses in Western Canada. Sci. Agric. 16 : 608-613. 1936.

A DISEASE OF THE EUROPEAN SPRUCE SAWFLY, *GILPINIA HERCYNIAE* (HTG.), AND ITS PLACE IN NATURAL CONTROL[1]

R. E. Balch[2] and F. T. Bird[3]

Dominion Entomological Laboratory, Fredericton, N.B.

[Received for publication July 15, 1944]

The European spruce sawfly, *Gilpinia hercyniae* (Htg.), was apparently introduced to Canada at least several decades ago (1). When first discovered in 1930, a large outbreak had already developed. The history of this outbreak has been described (2, 3). It reached its peak about 1938, when some 12,000 square miles were estimated as being heavily infested. During the next few years the numbers of the insect declined, until by 1943 no important defoliation was being caused.

The decline of the outbreak coincided with the appearance of high percentages of larval mortality due to disease. This paper will discuss the evidence that the disease was responsible for the decline of the outbreak. It will also give some preliminary information regarding the nature of the disease pending the completion of further experimental studies to be reported in full later by the junior author.

HISTORY OF DISEASE

The first evidence of a disease affecting the sawfly was obtained in the laboratory in 1936. During 1934 and 1935 continuous rearings of pure lines of the insect had been carried on by Mr. C. C. Smith for as many as twenty-five generations, without any sign of disease. Early in 1936, small percentages of the larvae began to die. The amount of mortality increased steadily until by 1939 it had become impossible to rear a single larva in the laboratory by ordinary methods.

In the forest only rare individuals which might have been diseased were observed until 1938. During the latter part of this year diseased larvae became numerous in some parts of New Brunswick and were noted by Dowden (8) in heavily infested areas in Vermont and New Hampshire. In 1939 mortality was high at these points and was observed over much wider areas. In 1940 Dowden concluded that the disease was responsible for controlling the outbreaks in Vermont and New Hampshire. The same year Peirson (11) reported that it was prevalent in parts of Maine, but did not consider it a reliable factor of control.

In Canada, from 1939 to 1942 the epidemic appeared to spread from south to north. Disease was not evident on this laboratory's plots in central Gaspe, Quebec, until 1940 and did not cause any striking reduction in population there until 1942. The first report of its occurrence on the north shore of the St. Lawrence was in 1940 (5). By 1942, however, it was known to be distributed throughout the greater part of the range of the sawfly. Samples of larvae collected from numerous localities scattered from Nova Scotia to Lake Ontario have shown both the external and internal symptoms.

[1] Contribution No. 2320, Division of Entomology, Science Service, Department of Agriculture, Ottawa, Canada.
[2] Officer-in-charge.
[3] Agricultural Assistant .

The disease was first noticed in heavily infested areas but has been found since causing considerable mortality in light infestations. Since 1940 the authors have never failed to find it wherever the sawfly has been moderately numerous. It has also been prevalent in stands which have never been more than lightly infested, and were in some cases over 100 miles from the nearest heavy infestation. Dr. C. E. Atwood and Mr. K. E. Stewart, of this Division, however, have reported on areas in Ontario which were apparently still free from the disease in 1942. No evidence has been found of its presence in Newfoundland. These areas are the farthest removed from the main heavily infested region. It appears that a high density of host population may have been necessary, or favourable, to the development of the epidemic, but that it rapidly achieved a momentum which carried it long distances more or less regardless of the density of the population of the host. In 1943 it was still causing considerable mortality in lightly infested stands.

There is no definite evidence regarding the origin of the disease. It is not improbable that it was introduced to this continent from Europe with parasite material. Dr. W. R. Thompson of the Imperial Parasite Service has kindly supplied information regarding a study of a disease of *Gilpinia polytoma* (Htg.), made during the course of parasite investigations in Europe, which strongly suggests that it is the same as the disease in Canada. Dr. K. R. S. Morris has also reported a disease attacking this species in central Europe. Apparently, *Gilpinia pallida* (Klug.), *Diprion pini* (Shrank) and *Neodiprion sertifer* (Geoff.) are affected by the same disease.

VALUE AS A CONTROL FACTOR

Natural Control Before Disease Appeared

In order to estimate the effect of a new factor of control it is necessary to know something of the nature of the control complex before this factor was added.

Since 1930 the Fredericton laboratory has studied the population of the sawfly and the factors controlling it (3). Most of the data have been obtained from seven plots in Quebec and New Brunswick. On all of these for periods of from 4 to 8 years the cocoon population has been estimated annually by a method of sampling which has been described by Prebble (13). On four of them the larvae dropping from the trees have also been recorded daily for a number of years. This was accomplished by means of trays, corresponding in size and method of location under the trees to the ground quadrates used for cocoon sampling (10). Random samples of larvae and cocoons have also been taken periodically from numerous points throughout the Maritime Provinces and the Gaspe area. Through the Forest Insect Survey, 5,865 collections of larvae and 1,202 collections of cocoons have been received and analyzed at Fredericton. Each year studies have been made of adult emergence, oviposition, and egg mortality. The various factors of natural control have been investigated by laboratory and field experiments. Although it is difficult with this insect to obtain satisfactory estimates of the population in the adult and egg stages, the above work has provided a fairly complete picture of the progress of the outbreak and the factors determining local and general population trends.

Some of the results have been published (2, 3, 9, 12, 14). The following is an attempt to summarize them for the period preceding the appearance of disease.

The sawfly had evidently increased rapidly in the Gaspe for some years prior to its discovery in 1930. Between 1930 and 1938 the area of heavy infestation spread over most of the peninsula, and heavy infestations developed throughout New Brunswick, in northern Maine, in parts of Vermont and New Hampshire, and to the west of the Gaspe in Quebec. At the same time moderate or light infestations occurred through all other parts of the spruce forests of this region and extended from Nova Scotia to the north shore of the St. Lawrence and west to Ontario.

The rate of increase during this time was irregular, owing chiefly to annual and regional fluctuations in the percentage of eonymphs remaining in diapause in the cocoon (12). Higher percentages of diapause caused lower populations of feeding larvae, increased cocoon mortality, and checked the rate of increase. The cocoon population, however, tended to rise, irregularly but persistently, until limited by the supply of foliage. It was evident that although many control factors were operating on the sawfly, the survival rate in the main types of spruce forest was sufficient to bring about an increase in its numbers until the upward population trend was reversed by a shortage of food. Owing to the reserve of cocoons in diapause, and to the reluctance of the larvae to eat the new foliage, this drop in numbers was generally rather gradual, and during the process the defoliation of the trees was often completed. Toward the south, however, diapause tendency was low and population fluctuations were more violent.

The factors controlling the rate of increase have varied somewhat in relative importance in different seasons, regions and forest types. They have been, however, much the same in all the places studied and in a general way may be summarized by stages as follows:

The Egg. No natural enemies of the egg have been found and no important mortality has resulted from climatic factors. Some are lost through the drying and dropping of needles in which they are laid. The percentage hatch has generally been over 90 and close to 95.

The Larva. The feeding larval stages are well adapted to the climatic conditions under which spruce grows. A small percentage of the first instar dies from rain and unknown causes. The larvae are resistant to several degrees of frost but in cool seasons some mature too late to reach the cocoon stage before winter. A number of the immature larvae drop from the trees but many of these crawl back to the foliage. Birds and insect predators take a moderate toll of all instars, but, as shown by Reeks (14), native parasites have accounted for no more than 0.02%. Shortage of food in the later stages of outbreaks has been the cause of the greatest amount of larval mortality.

The Cocoon. In the dormant condition in the cocoon the sawfly will survive temperatures lower than any experienced in the forest floor. It is also resistant to the effects of extreme dry or wet weather, although some mortality results from prolonged wet conditions on poorly drained sites. Dry weather may cause mortality indirectly by prolonging diapause and thus increasing length of exposure to predators (12). The greatest

mortality in the cocoon is caused by small mammals which destroy about half the cocoons during a period of outbreak (9). The percentage thus destroyed is greatest under conditions of high diapause and following a high density of population.

Some idea of the total mortality in the cocoon can be gained from the fact that samples from beneath dead trees in central Gaspe showed that during the period of outbreak 82% failed to produce adults. Samples taken in 1943 on two plots in central New Brunswick, where there is less diapause, showed percentages of 62 and 68.

The Adult. There is little evidence of important control in the adult stage. Most adults apparently succeed in laying their full complement of eggs. This has remained fairly constant at around 45 per female, except when reduced by poor feeding conditions in the preceding larval stage. Some adults are destroyed by birds but in the typical spruce forest this number does not seem to be large. Climatic conditions are favourable except for a few which emerge too late in the season to complete oviposition.

The destructiveness of the sawfly up to 1938 may therefore be attributed to the fact that it had been introduced to a region where its food was plentiful over vast areas, where the climate was favourable and the biotic factors of control were insufficient to prevent an increase of population until the factor of food shortage was added. The latter appeared to be the only truly density-dependent factor of importance.

By 1938, however, several species of introduced parasites had become well established and began to exert considerable additional control in many parts of the infested area (2, 4). At the same time the first evidence was obtained that disease was affecting the sawfly, in the more southerly parts of its range. In 1939 both disease and parasites increased in effectiveness but the disease began to compete successfully with the parasites and became the chief factor in bringing about a general reduction of the outbreak (2, 9). If the disease disappears, the introduced parasites may again become important in maintaining control.

Mortality Caused by Disease

Some indications of the considerable amount of mortality caused by the disease have been given in the literature (2, 6). Dowden (8) described the large number of dead larvae in heavily infested areas in New Hampshire and Vermont in 1939 and noted that disease was also prevalent in light infestations. Dirks (7) reported in 1942 that on plots in Maine, 97% of the larvae which dropped were dead and that samples beaten from trees in August showed from 63 to 98% disease.

Exact measurement of the percentage of a generation which is killed is difficult, however. It has been attempted in different ways.

1. By beating the larvae from low-growing trees on to a 7 × 9 ft. sheet, with a 10-ft. pole. This gives an estimate only of the population and its condition at the time of sampling. It gives no information on the number of larvae which fell before sampling, and once the larvae have been disturbed it is impossible to tell how many of the healthy larvae would have become infected before maturity. Also, many diseased larvae adhere to the foliage and are not removed by beating.

2. By rearing known numbers of larvae from the egg on isolated branches over cotton mats. This involves only small numbers under conditions not typical of the forest. It provides information on the seasonal pro. gress of the disease and the degree to which the various instars are affected.

3. By recording daily throughout the season the stage and condition of the larvae dropping from the trees on 2 × 2 ft. trays, as mentioned above. The trays were placed under trees distributed alternately among those used for cocoon samples. This method gives definite information on the number surviving to the sixth stage but the number of diseased larvae recorded is considerably less than the total because the majority of diseased larvae adhere to the foliage.

If these limitations are recognized, data of some value can be obtained. The third method is the only one which is of much use for estimating percentages of mortality in the stand. In Tables 1 and 2 are shown the results on two plots in central New Brunswick where daily records were

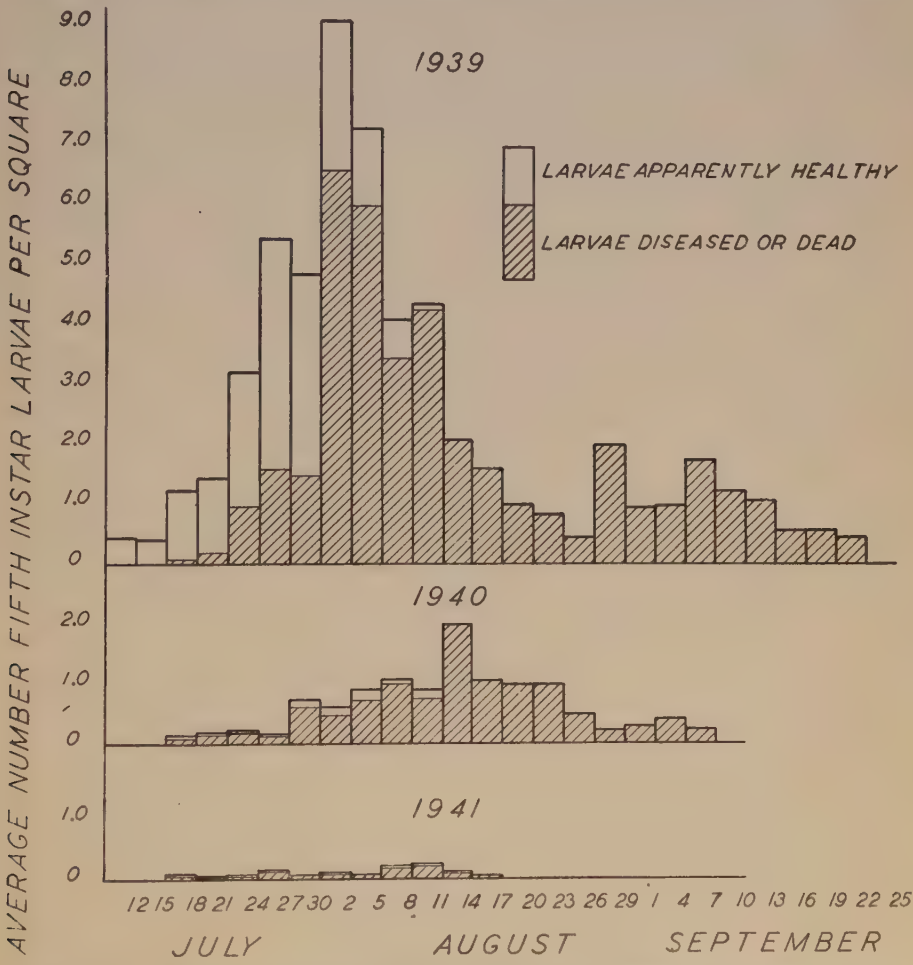


FIGURE 1. Drop of fifth stage larvae on Plot 1, 1939-41, shown as apparently healthy diseased.

possible from 1938 to 1941[4]. The trays all had cotton bottoms except those used at Young's Brook in 1938 and 1939. These had wire screens through which some of the young larvae escaped. The sides were treated with tanglefoot and so constructed as to prevent escape.

In Figure 1 is shown the drop of fifth stage larvae by 3-day periods on Plot 1 for 1939-41. This indicates the increasing effectiveness of the disease as the summer progresses. Only the earlier larvae of the first generation had any chance of survival. It also gives a good idea of the degree of mortality and the reduction in population each year.

TABLE 1.—LARVAL DROP AT YOUNG'S BROOK (PLOT 1) ON 44 TRAYS, 2 × 2 FT.

Stage	1938			1939			1940			1941		
	No. of larvae	Percentage diseased	Percentage of total diseased	No. of larvae	Percentage diseased	Percentage of total diseased	No. of larvae	Percentage diseased	Percentage of total diseased	No. of larvae	Percentage diseased	Percentage of total diseased
		%	%		%	%		%	%		%	%
I	—	—	—	6	33.3	0.07	58	98.2	2.8	1	100	0.5
II	—	—	—	153	43.8	2.4	402	96.8	19.5	18	87.5	11.4
III	—	—	—	801	43.4	12.4	601	97.9	25.7	45	88.9	21.7
IV	—	—	—	409	51.8	7.6	408	96.5	19.8	51	90.2	25.5
V	1088	4.7	—	3118	70.2	78.8	607	91.4	27.9	87	88.8	40.7
VI	1389	—	—	465	12.7	2.1	19	26.3	0.2	2	50.0	0.5
Total all stages				4952	58.1	—	2095	94.2	—	210	86.2	—
Mortality if all dropped				—	91.8	—	—	99.3	—	—	99.5	—
Mortality if half dropped				—	94.8	—	—	99.7	—	—	99.7	—

TABLE 2.—LARVAL DROP AT ACADIA STATION (PLOT 3) ON 50 TRAYS, 2 × 2 FT.

Stage	1938			1939			1940			1941		
	No. of larvae	Percentage diseased	Percentage of total diseased	No. of larvae	Percentage diseased	Percentage of total diseased	No. of larvae	Percentage diseased	Percentage of total diseased	No. of larvae	Percentage diseased	Percentage of total diseased
		%	%		%	%		%	%		%	%
I	1	0	0	8	87.5	1.1	4	100	1.5	0	—	—
II	8	0	0	17	70.5	2.0	11	100	4.3	1	100	1.4
III	23	4.3	0.5	91	77.0	11.8	23	95.7	8.5	4	25.5	1.4
IV	41	31.7	6.9	104	61.8	10.9	44	90.1	15.5	10	30.0	4.1
V	301	54.8	88.2	712	59.1	71.0	208	95.1	77.0	90	74.4	93.0
VI	590	1.3	4.2	397	4.5	3.0	23	8.7	0.7	11	0	—
Total	964	19.4	—	1329	56.5	—	333	88.6	—	116	65.5	—
Mortality if all dropped		39.7	—	—	71.5	—	—	93.4	—	—	90.5	—
Mortality if half diseased dropped		49.4	—	—	81.8	—	—	96.5	—	—	94.3	—

[4] These plots were established by W. A. Reeks and M. L. Prebble and we are indebted to them and R. F. Morris for supplying most of the original data.

The annual reduction in larval population is best indicated by the number of larvae reaching the sixth stage in a healthy condition. This is a non-feeding stage which does not become diseased unless it was infected in the previous stage. It remains on the tree for one, or two days, then drops to the ground to spin the cocoon.

On Plot 1, for instance, where the infestation was heavy in 1936 and 1937, the total dropping as sixth stage in 1938 was 1,389. The number in each of the following three years was 465, 19, and 2. On Plot 3, where the infestation had been only moderate, the number of sixth stage dropping in the years 1938 to 1941 was 590, 397, 23, and 11. The reduction was greater and more rapid on the heavily infested plot.

The degree of larval mortality is best calculated by comparing the number of healthy sixth stage larvae with the total of all stages. For instance, in 1939 on Plot 1, 4,952 larvae dropped, of which 406 were healthy sixth. If it were assumed that all the larvae dropped, the percentage mortality would be 91.8. Similar calculations for 1940 give a mortality of 99.3%. This method, however, gives an underestimate since the majority of diseased larvae die on the trees and remain there for some time. Gradually, rain, wind and snow dislodge them, but generally not until after the recording of drop has ceased. Laboratory experiments and calculations from frass-drop measurements by Morris (10) suggest that about 80% remain on the foliage. It will be conservative to assume that half the diseased larvae do not drop in time to be recorded. If this is done the total number of larvae in the case of Plot 1 in 1939 was 4,952 plus 58.1%, or 7,829. The percentage mortality would then be 94.8 The corresponding figure for the next two years is 99.7.

This method of calculating the larval mortality in a stand is the most accurate one at present available[5], but, in addition to the uncertainty regarding the number adhering to the foliage the following possible sources of error must be recognized: (1) If all sizes of larvae are not very carefully collected at least once a day the total larvae, and hence the percentage mortality, will be under-estimated; (2) Stages 1 to 5 which are recorded as healthy would often have become diseased before reaching the sixth stage; (3) Some of the healthy immature stages may regain the foliage and be recorded twice. Under the conditions on this laboratory's plots these errors are thought to be small, but to tend toward underestimation of mortality.

Mortality from Disease Compared with Total Mortality

The extent to which this larval mortality was reflected in the over-wintering population of cocoons is indicated in Table 3. Figures are given for a plot near Dunbar Creek (Plot 2) as well as for the plots at Young's Brook (Plot 1) and Acadia Station (Plot 3). All are within 25 miles of each other. They represent three degrees of infestation.

It will be seen that in all cases the first decrease in cocoon population occurred following the season of 1939, when the disease was first recognized as an important control factor and larval mortality on two of the plots was estimated at 82 and 95%. Disease was present in 1938 and killed a good

[5] Measurement of frass-drop appears to provide a more satisfactory method, as shown recently by Morris (10).

many larvae in the latter part of the summer. Data on larval drop for Plot 3 indicate a mortality that year of 50%. They are incomplete for Plot 1, but the number of sixth stage was about three times as great as in 1939 and the mortality was evidently insufficient to prevent an increase in cocoon population on all plots. The most striking reductions occurred following the seasons of 1940 and 1941, when the percentage larval mortality was not less than 99.7% on Plot 1 and 96.5 and 94.3% on Plot 3.

Although the estimated percentages of mortality due to disease are high, and there is an obviously close relation between the amount of disease and the reduction in the outbreak, it is not sufficient to quote such figures without considering what effect they would have on population trend and what relation they have to the total mortality. The importance of a percentage mortality figure depends on sex ratio and number of eggs laid per female, as well as the habits of the insect and the methods by which data are obtained.

The problem of determining the exact rôle of any single factor of control is difficult and often baffling. The difficulty lies in obtaining reliable data on all the interacting factors involved. In the present case an attempt to do so would seem to be justified since the mortality from disease was sufficiently high to make the other factors relatively unimportant. Thus errors due to the use of approximate estimations based on inadequate data are less serious. The attempt is made, however, not so much to present exact estimates of mortality as to indicate some aspects of the problem which must be considered, no matter how much it is simplified. Percentages are shown to the first decimal point regardless of the significance of the data, to demonstrate the importance of fractional changes in such percentages as they approach 100. The results only serve to emphasize the great care necessary in obtaining data on percentages of mortality and the importance of relating them to the habits and reproductive rate of the insect.

In comparing the estimated mortality from disease with the total mortality from all factors as shown by the cocoon counts it is necessary to consider the habit of diapause and the two overlapping generations per year.

TABLE 3.—COCOON POPULATION ON THREE PLOTS IN NEW BRUNSWICK*

(200 sq. ft. per plot).

——	1937	1938	1939	1940	1941	1942	1943
1. Young's Brook (heavy)	31.8	66.7	95.8	28.6	1.1	0	0.04
2. Dunbar (medium heavy)	4.0	37.2	55.6	26.8	0.9	0.04	0.12
3. Acadia Station (medium)	—	9.2	21.0	5.5	0.09	0.24	0.20

* Average Number of Sound Cocoons in Spring Per 4 sq. ft.

In this district in 1939 and 1940 approximately 30% of the cocoons collected in the spring and observed under natural conditions remained in diapause. Studies of mortality in the cocoon stage indicate that in an average year almost 80% of these dormant cocoons would be destroyed by small mammals and other causes. The great majority of the remainder would emerge the following year. Thus spring counts would contain about $\frac{30 \times 20}{100}$ or 6% of the cocoons counted the previous spring, which had

remained in diapause and escaped destruction, in addition to those formed the previous summer. This hold-over of dormant cocoons prevents the effect of larval mortality from being fully reflected in the cocoon population of the following spring. For this reason 100% larval mortality would not wipe out a population unless repeated for at least two successive years. In the Gaspe, where diapause tendency is much stronger, high larval mortality reduces the cocoon population more gradually than in New Brunswick and more southerly areas (2, 12).

Of the cocoons formed by the first generation, a variable percentage produces adults for a second generation the same year. In central New Brunswick during 1937 and 1938 the authors estimate this at approximately 25%. Data are lacking for the following years but it would certainly be higher and probably close to 50%. This is because there is greater emergence from early than late cocoons, and when the disease is prevalent only the earlier larvae succeed in reaching the cocoon stage (Figure 1).

The overlapping of the two generations makes it impossible to study them separately under natural conditions with any degree of accuracy. It is difficult, however, to present a true picture of natural control unless some attempt is made to calculate the mortality in terms of each generation.

Before the disease appeared there was no evidence that there was any consistent difference in the amount of mortality suffered by the two generations outside the cocoon. It is assumed, therefore, that it was approximately equal in each generation. On the other hand, after the disease became prevalent, from 1939 to 1941, the mortality suffered by the second generation was 100%. This can be seen from Figure 1, for no healthy larvae dropped after the middle of August and second-generation larvae do not reach the fifth stage until after that time. The authors have therefore assumed 100% mortality in the second generation during these years.

In Table 4 are shown the following which have been calculated from the cocoon counts in Table 3.

1. *Index of Population Trend.* This is the number of sound cocoons in the spring expressed as a percentage of the number of sound cocoons in the previous spring.

TABLE 4.—INDEX OF POPULATION TREND (I) AND TOTAL MORTALITY PER GENERATION (M_1 AND M_2) CALCULATED FROM TABLE 3

—			1937–8	1938–9	1939–40	1940–1	1941–2	1942–3
Plot 1.	Index population trend (I)		210	144	30	4	0?	200?
Young's Brook	Total Percentage Mortality	$M_1 = M_2 =$	95.0	96.3	98.6	100?	100?	—
		$M_2 = 100, M_1 =$	—	—	98.5	100?	100?	—
Plot 2.	Index population trend (I)		903	149	48	34	4	300?
Dunbar	Total Percentage Mortality	$M_1 = M_2 =$	86.9	96.2	97.6	98.4	100?	—
		$M_2 = 100, M_1 =$	—	—	97.3	98.2	100?	—
Plot 3.	Index population trend (I)		—	228	26	16	27	80?
Acadia	Total Percentage Mortality	$M_1 = M_2 =$	—	94.7	98.8	99.4	98.8	—
		$M_2 = 100, M_1 =$	—	—	98.7	99.4	98.7	—

2. *Total Mortality per Generation.* This is the total percentage of a generation killed by all factors up to the time of the following spring. It does not include mortality to overwintering cocoons remaining in diapause during the year. It is necessarily based on sex ratio, number of eggs laid per female, and percentages of diapause.

Since males are rare (less than 1 in 1000), the sex ratio, or percentage of females divided by 100, is taken as 1.

The number of eggs which a female is capable of laying varies somewhat with the conditions of feeding of the larva from which she developed, and other environmental and inherent factors. It is therefore necessary to estimate this from an average of the number laid by a sample of females under natural conditions but protected from external causes of mortality. This has been found to remain fairly constant over a period of years and to approximate 45.

If I = index of population trend, or

$$\frac{\text{cocoons per sq. ft. present year}}{\text{cocoons per sq. ft. previous year}} \times 100,$$

M_1 (or M_2) = total percentage mortality of first (or second) generation,

E_1 = percentage emergence of adults from overwintering cocoons,

E_2 = percentage emergence from cocoons of first generation,

R = average number of eggs per female,

D = percentage of overwintering cocoons surviving in diapause,

then $I = 100\, E_1\, R\, (1\text{-}M_1)\, (1\text{-}E_2) + 100\, E_1\, R\, (1\text{-}M_1)\, E_2\, R\, (1\text{-}M_2) + 100\, D.$

If $E_1 = \frac{70}{100}$, $R = 45$, $D = \frac{6}{100}$,

then $I = 3150\, (1\text{-}M_1)\, (1\text{-}E_2) + 141750\, E_2\, (1\text{-}M_1)\, (1\text{-}M_2) + 6.$

Prior to 1939 it is assumed that $M_1 = M_2 = M$, and $E_2 = \frac{25}{100}$. Then

$I = 2362.5\, (1\text{-}M) + 35437.5\, (1\text{-}M)^2 + 6,$

which solves to

$$M = 1 - \frac{\sqrt{I + 33.31} - 6.27}{188.25}$$

If, during the years 1939-41, $M_2 = \frac{100}{100}$ and $E_2 = \frac{50}{100}$, then

$$I - 6 = 1575\, (1\text{-}M_1),$$

$$\text{or } M_1 = 1 - \frac{1 - 6.}{1575}$$

In considering the control effect of the various values for M it is helpful to know the total mortality in each generation which would be necessary to maintain a level population (i.e. $I = 100$). Assuming it to be equal for both generations, a mortality of 97.2% would be necessary. If the mortality of the second generation were 100%, the mortality of the

first would have to be 94.23%. If there were no diapause, a uniform mortality of $\frac{44}{45}$ or 97.8% would be needed in each generation to maintain a static population. This is Bremer's "normal coefficient of destruction" for one generation as quoted by Uvarov (15).

The percentages of larval mortality from disease in Tables 1 and 2 are in all cases less than the total mortality in Table 4. For instance, on Plot 1 in 1939 larval mortality was 94.8%, total mortality 98.6%; in 1940 the respective percentages were 99.7 and 100. The percentages approximated more closely as the disease became more effective. These differences are of course to be expected, since the other factors of control continued to operate after the appearance of the disease.

Adult and egg mortality probably remained much the same but many factors controlling the larval and cocoon stages were directly affected by the lowered density of the host population. Scarcity of foliage, which had become a factor of some importance on Plot 1 by 1937, although not on the other plots, ceased to have any affect after 1939. The percentages killed by introduced parasites at first increased as the population declined, and then decreased. There is some evidence that the percentages destroyed by *Podisus* sp. and small mammals may have behaved similarly (9). This seems to be indicated by those cases in Table 4 where *I* is less than 6. Occasionally there was overlapping as when infected larvae were attacked by *Podisus* or *Exenterus* spp.

In spite of uncertainty regarding the exact control value of other factors since 1939, the figures for these plots indicate fairly clearly the importance of the disease in bringing about the end of the outbreak. They serve to confirm the conclusions drawn from less intensive sampling methods used throughout the infested area. During 1939-41 it was undoubtedly the major control factor and capable of reducing the sawfly numbers regardless of other factors. This was clearly the case on Plot 1 in 1940 and 1941, when larval mortality was conservatively estimated at 99.7%. Had there been no mortality in the adult or egg stage the percentage killed by disease probably would have been greater owing to higher density of larval population, and the total mortality much the same.

Prior to the appearance of disease, other factors were causing mortality of from 85 to 95% or more. The parasites, which were increasing rapidly, may have been capable of bringing the "average" generation mortality above the necessary 97% before scarcity of foliage and dying of trees added the factor of starvation. The disease, however, accomplished this before the potential value of the parasites could be determined and it destroyed so large a proportion of the population that other factors became of minor importance. It has continued as the dominant factor in the control complex at least up to 1942, but will probably not remain so after the population has been reduced to a certain level. Although the values shown for *I* in 1942-43 are not significant, they suggest that this level may have already been reached.

NATURE OF DISEASE

Laboratory experiments were limited at first by inability to rear larvae free from disease. Larvae were collected from disease-free areas in Ontario and shipped to Fredericton in sterilized boxes. They were reared by an

assistant isolated from the regular laboratory in another building. Foliage was used from shade-trees separated from the forest. Experiments were carried out within a few days with fair controls, but the precautions taken were insufficient to prevent eventual infection.

The difficulty was finally overcome by rearing larvae singly in special containers which could be sterilized by heat and used like a bacterial culture tube. By careful observance of the usual precautions in bacteriological work it has been found possible to rear disease-free lots continuously, even in the same incubator with infected lots.

External Symptoms

By infecting a number of larvae and examining them at 12-hour intervals, the process of infection has been followed up to death. The period from infection to appearance of first external symptoms varies with the temperature at which the larvae are reared. At 70° F. it is about 96 hours, with death occurring 2 or 3 days later. The period of infection to death at a mean temperature of 66° F. has been found to be 6 days and at 51° F., 11 days.

The first external symptom of infection among third, fourth and fifth stage larvae is a faint yellow discoloration of the third to fifth abdominal segments. In the case of first and second stage larvae there is a similar whitish discoloration but, owing to the small size of the early instars the first symptoms are not easily detected and in many intsances are not observed. As the infectious process continues, the discoloured area becomes more pronounced and soon the larva loses its healthy green colour, changing first to yellow-green and after death to dark brown or black. Infected larvae cease to feed and become inactive. There is also a shortening of the body, not unlike that of larvae which have been starved. Diseased larvae often exude a dark brown fluid from the anus which cements the cadaver to the needle on which it has been feeding. The yellow-green protective fluid which is emitted from the mouth of healthy larvae when disturbed becomes milky-white in colour when the larvae are suffering from disease.

After death the larva is frequently completely flaccid and it is difficult to remove it from the foliage without rupturing the integument and liberating the liquid contents. There is no offensive odour. The cadavers may fall to the ground or remain attached to the foliage in a feeding position or suspended from the foliage by either extremity.

Internal Symptoms

If a smear of the body fluids of diseased larvae is examined with a high power dry or oil immersion lens it will be found to contain, besides the elements of disorganized tissues, myriads of polyhedral bodies. The average polyhedron measures 1.3 microns in diameter, ranging from 0.5 to 1.8 microns. Their shape varies as much as their size, but in general the form is that of a polyhedron with more or less rounded corners. They never assume the shape of a perfect sphere. They are highly refractive and resistant to stains.

The pathological process is concerned with the digestive tract and usually results in the complete destruction of the mid-gut. The cells of the epithelium of the mesenteron become enlarged. The polyhedral bodies are formed within the enlarged nuclei, from which they eventually escape. These nuclei appear like small dark bubbles when examined microscopically in the fresh state with a low power lens.

The digestive epithelium of healthy larvae is translucent and the gut appears green in colour, due to the large amount of partially digested food material which it contains. The digestive epithelium of a diseased larva becomes opaque and milky-white in colour and the gut is devoid of food.

The transition from an apparently healthy gut to a diseased gut is extremely rapid and in most cases the gut is apparently healthy 12 hours before the advanced symptoms.

The Pathogen

The blood and tissues of large numbers of diseased larvae have been examined and a good many cultures have been made. In most cases no bacteria or other micro-organisms are present until after death. Occasionally bacteria have been found in living diseased larvae but these appear to be of a secondary nature and associated with unfavourable rearing conditions.

From the external and internal symptoms, the presence of polyhedral bodies, and the pathological processes the disease appears similar to the virus or "wilt" diseases of various lepidoptera (15).

Experiments with Berkefeld V and N candled filtrates, however, have shown that the pathogen has been removed during the process of filtration. Further attempts with different techniques must be made before filterability can be definitely determined.

Methods of Transmission

Infection occurs by way of the mouth and larvae are easily infected by allowing them to feed on foliage which has been smeared or sprayed with aqueous dilutions of the body fluids of diseased living or dead larvae.

The apparently almost simultaneous appearance of the disease over large areas in both heavy and light infestations and the degree of control obtained within a short period of two or three years give some idea of the extreme-contagiousness of the disease and its efficient means of spread. In carefully controlled laboratory experiments, however, when the air has been relatively still, healthy larvae have only become infected after direct contact with diseased larvae or surfaces which have been contaminated by them. The spread of the disease through the air is dependent on the presence of water or dust particles which have been in contact with the pathogen and on air currents sufficient to carry them. It is improbable that spread by this means is sufficient alone to explain the rapid dissemination in nature. Experiments now in progress indicate that under certain conditions the pathogen may be carried into the cocoon without killing the insect and the emerging adult is contaminated. This may be an important means of overwintering and spread since the adults often fly long bistances (4).

It is uncertain whether the pathogen overwinters on the foliage. Most of the cadavers are washed off before spring, and snow and rain are probably important cleansing agents. One experiment has shown that contaminated foliage lost its infectiveness during one month of sub-zero weather. The disease does not appear in the field until about the middle of July and this shows that the foliage is not heavily contaminated in the spring. On the other hand, the pathogen has survived in cadavers stored at just below freezing point for 13 months and in aqueous dilutions at room temperature for at least three months.

Resistance of Different Stages

The evidence all indicates that the disease originates in the alimentary tract and can only infect the five feeding larval stages. The sixth stage, eonymph, pronymph, pupa, and adult have remained uninfected even after immersion in water extract of diseased larvae.

The gut is normally evacuated by the sixth stage before the cocoon is spun (12). It has been found that if the period between the infection of a fifth stage larva and the evacuation of the gut is less than the period of incubation, normal development to the adult stage can take place. Although the adult is not affected, it can transmit the disease to some of its offspring, as already mentioned. It has not yet been determined whether the pathogen can be carried through the egg stage but the egg itself does not appear to be affected.

If, however, the time of infection of a fifth stage larva is such that lesions occur in the gut shortly before moulting, it may reach the sixth stage but be unable to evacuate the gut. A cocoon may be formed but death takes place in the eonymphal, or occasionally the pronymphal, stage. This explains how mortality from disease may sometimes occur within the cocoon. Such cases can generally be recognized by the dark flaccid appearance of the dead larva and the rather loosely spun cocoon.

The amount of this mortality is small when, as in 1940-42, the disease appears in quantity during the early stages of development. It is greatest when disease appears after most of the larvae are approaching maturity. During 1938 and 1939, eight collections made between Aug. 18 and Nov. 4, comprising some 6,000 cocoons, showed mortality of this kind ranging from 0.5 to 3.4%.

We have observed no cases of individual immunity or resistance in the feeding larval stages. All larvae fed contaminated foliage in experiments have died. Those which have survived the epidemic in the forest appear to have escaped infection by chance and in heavy infestations were confined to those which developed very early. The higher the density of the sawfly population, the lower has been the rate of survival. A thelytokous and relatively homozygous insect like the sawfly might be expected to show little variation in susceptibility. However, if the sawfly population in

North America has not previously been exposed to the disease, there can have been little time for potential resistance in the population to have developed through selection or other means of adaptation.

Epidemiology

Up to the present there is very little to suggest that the disease is greatly influenced by weather conditions. Density of sawfly population seems to be the most important factor determining its control effect. Although it has proved remarkably effective under conditions of light infestation, there is no doubt that the percentage of disease increases with the numbers of its host. This increase is independent of secondary effects of crowding, such as shortage of food.

There is probably a minimum level of population on which the disease can maintain itself, once all the adults have emerged from cocoons formed by infected larvae as described above. It is already becoming less prevalent at points in New Brunswick and may disappear from considerable areas to reappear only after new outbreaks of the insect develop.

The possibility of storing the pathogen in virulent form so that it can be re-established if necessary is being investigated. Preliminary experiments have shown that it can be introduced to new areas by spraying foliage with a water extract of diseased larvae.

ACKNOWLEDGMENTS

The authors wish to acknowledge considerable assistance rendered by Mr. D. J. MacLeod and Mr. J. L. Howatt of the Dominion Laboratory of Plant Pathology at Fredericton in the early stages of the work, particularly in connection with the preparation and testing of filtrates. Dr. C. E. Atwood, Dr. L. L. Daviault and Mr. K. E. Stewart of the Division of Entomology, Science Service, Dominion Department of Agriculture, have assisted generously in carrying out experiments on the establishment of the disease in new areas in Ontario and Quebec. Acknowledgment is extended to Dr. R. W. Glaser of the Rockefeller Institute for Medical Research for suggestions.

REFERENCES

1. Balch, R. E., W. A. Reeks and S. G. Smith. Separation of the European spruce sawfly in America from *Gilpinia polytoma* (Htg.) and evidence of its introduction. Can. Ent. 73 : 198-203. 1941.

2. Balch, R. E. Annual reports on the European spruce sawfly outbreak. Ann. Rept. Dept. of Lands and Forests of Nova Scotia, Halifax, N.S. 1934 to 1942.

3. Balch, R. E. The outbreak of the European spruce sawfly in Canada and some important features of its bionomics. Jour. Econ. Ent. 32 : 412-418.

4. Baird, A. B. A review of the spruce sawfly parasite situation. Woodlands Sec., Can. Pulp and Paper Assn. Index No. 549 (F-3). 1940.

5. Daviault, L. L. La mouche a scie Europeenne de l'epinette dans la forets du nord du St-Laurent. La Foret Quebecoise 3 : 3-7. 1941.

6. de Gryse, J. J. Brief note on the so-called mysterious disease of the spruce sawfly. For. Chron. 17 : 43-44. 1941.

7. Dirks, C. O. Report of work and observations on the European spruce sawfly in Maine, 1942. Mimeo. Univ. of Maine. 1943.

8. Dowden, P. B. Larval disease prevalent in heavy infestations of the European spruce sawfly in southern New Hampshire and Vermont. Jour. of For. 38 : 970-972. 1940.

9. Morris, R. F. Preliminary notes on the natural control of the European spruce sawfly by small mammals. Can. Ent. 74 : 197-202. 1942.

10. Morris, R. F. The use of frass-drop measurement in forest insect investigations, with particular reference to the European spruce sawfly, *Gilpinia hercyniae* (Htg.). MS. Div. of Ent., Dept. of Agric., Ottawa, Can. 1944. To be published.

11. Peirson, H. B. Control work on the European spruce sawfly in 1940. 23rd Rept. of Forest Commissioner, Augusta, Maine. 1941.

12. Prebble, M. L. The diapause and related phenomena in *Gilpinia polytoma* (Htg.). Can. Jour. Res. D, 19 : 295-322; 323-346; 350-362; 417-436; 437-454. 1941.

13. Prebble, M. L. Sampling methods in population studies of the European spruce sawfly, *Gilpinia hercyniae* (Htg.), in Eastern Canada. Trans. Roy. Soc. Can. 37 : 93-126. 1943.

14. Reeks, W. A. Native insect parasites and predators attacking *Diprion polytomum* (Htg.) in Canada. 69th Ann. Rept. Ent. Soc. Ont. : 25-28. 1938.

15. Rivers, T. M. Filterable viruses. Ch. 8, pt. 2. Williams and Wilkins Co., Baltimore, Md. 1928.

16. Uvarov, B. P. Insects and climate. Trans. Ent. Soc. of London 79, p. 137. 1931.

A REVIEW OF THE NORTH AMERICAN SPECIES OF THE GENUS ARGYROTAENIA STEPHENS, (LEPIDOPTERA, TORTRICIDAE)[1]

T. N. Freeman

Science Service, Department of Agriculture, Ottawa, Ont.

[Received for publication August 21, 1944.]

This paper is presented in an endeavour to assist those engaged in the identification of the species of *Argyrotaenia* Steph. This genus is, at present, comprised of fifteen species which, as larvae, feed mainly on the foliage of coniferous and deciduous trees, and often occur abundantly enough to be of economic importance.

A study of the genitalia of both sexes showed that, because of the interspecific similarities, the characters found in these structures could not be relied upon for specific separation but appear to be quite usable for generic restriction. The segregation of the various species is, therefore, accomplished mainly by differences in wing pattern. These differences are tabulated to form an artificial key and are illustrated from photographs of specimens, or a series of specimens when it is desirable to indicate the variation of wing pattern within a species. In a few instances, illustrations of types and homotypes are included, thanks to the co-operation of the authorities at the Philadelphia Academy of Natural Sciences and at the American Museum of Natural History. The author's notes pertaining to these types have been incorporated in the text.

It is very difficult at the present time to obtain material or distributional data and, in consequence, the study has been based largely on specimens contained in the Canadian National Collection, and notes dealing with some of the more southern species are fragmentary. No attempt has been made to assemble a complete bibliography for each species, and only references to the taxonomic history are included. References to the vast economic literature, dealing with several of the species, may be readily obtained by consulting Colcord's indices of American economic entomology.

Argyrotaenia Stephens

Genotype: *Tortrix politana* Haworth

Stephens, 1852, List Spec. Anim. Brit. Mus., X (Lep.), 67.

Pierce and Metcalf, 1922, Gen. Tort. Lep. Br. Is., 1.

McDunnough, 1939, Check List Lep. Can. U.S.A. (Part 2), 57—*Argyrotaenia* Hbn. cited in error for *Argyrotaenia* Steph.

Cubitus of hind wing above without fringe of hair at base, but with a fringe on the base of the second anal; fore wing with radius 4 and 5 separate, the latter running to the apex or outer margin, medius 3 and cubitus 1 separate; hind wing with radius and medius approximate; fore wing smoothly scaled; palpi porrect, clavate or triangular; thorax with posterior crest; male antennae without notch at base.

---

[1] Contribution No. 2323, Division of Entomology, Science Service, Department of Agriculture, Ottawa.

Male genitalia: Claspers distinctly rounded; transtilla invaginated; cornuti broad, short, pointed and deciduous.

Female genitalia: Ductus bursa narrow, with a strong sclerotic thickening at the junction of the bursa.

Argyrotaenia is separated from *Eulia* Hbn. by the following characters:

Argyrotaenia: Hind wing with radius and medius approximate; aedoeagus broad; bursa membraneous.

Eulia: Hind wing with radius and medius stalked; aedoeagus aciculate; bursa spiculate, somewhat resembling that of the geometrid genus *Eupithecia*.

KEY TO THE NORTH AMERICAN SPECIES OF **Argyrotaenia** STEPH.

1. Hind wings white, at least on costal half.....2
   Hind wings smoky, brownish, or tawny.....6

2. Fore wing with a large central brown patch and with round, pure white or cream coloured patches surrounding the margin..... **alisellana** (Rob.)
   Fore wing obliquely crossed by one or more fascia.....3

3. Fore wing with numerous, small, light brown spots and two narrow, parallel, brown fascia..... **quercifoliana** (Fitch)
   Fore wing with single, broad, often suffused, median fasciae.....4

4. Fore wing with shining white area between the median band and the outer costal spot; fringe of hind wing without dark basal line..... **coloradana** (Fern.)
   Area between median band and outer costal spot not white but concolorous with the ground colour.....5

5. Second joint of labial palpi strongly tufted on upper side (fig. 2) and broadest at the middle, this giving it a triangular appearance..... **citrana** (Fern.)
   Second joint of labial palpi clavate, not tufted, widest at its apex (Fig. 1) **repertana** n. sp.

6. Fore wings brown or orange, with two narrow parallel darker fasciae.....7
   Fore wings more variegated, fascia when present much broader.....8

7. Fore wings bright orange..... **quadrifasciana** (Fern.)
   Fore wings brown..... **juglandana** (Fern.)

8. Fore wings rust coloured, with two or three very distinct silvery white costal-streaks **niscana** (Kft.)
   Fore wing without silvery white costal streaks, although complete whitish fascia may be present.....9

9. Base of fore wing outstandingly ocherous to the inner edge of the median band, at least on costal half.....10
   Base of fore wing may be somewhat ocherous but not standing out as a distinct ocherous basal patch.....11

10. Ocherous basal patch uniform over the whole basal area from costa to the dorsal margin. Rest of wing shining leaden-grey. Expanse ♂, 19 mm. Described from California..... **gloverana** (Wlshm.)
    Ocherous basal patch on costal half of fore wing only. Expanse 14–16.5 mm. a few males and all females of **velutinana** (Wlk.)

11. Fore wings reddish brown, irrorated with darker cross lines, or the bands of the wings with darker outer margins..... **tabulana** n. sp.
    Fore wings not irrorated with darker cross lines, or the bands not distinctly margined with darker shades.....12

12. Fore wings distinctly banded with reddish-brown, the outer margin of the basal patch extending from the dorsal margin to the costa. A pine feeder.. **pinatubana** (Kft.)
    Fore wings may have traces of reddish-brown banding but not distinctly so, and in such cases the outer margin of the basal patch does not extend to the costa.....13

13. Fore wing grey or greyish-white; basal patch usually obsolete; median fascia weak behind, very pronounced in costal region where it is more or less joined to outer costal spot to form a large elongate triangle which extends almost to apex of wing. Expanse 18–23 mm. . . . . **mariana** (Fern.)
 Fore wing may be greyish but not with large elongate costal triangle extending almost to apex of wing. 14

14. Outer edge of basal patch distinct from dorsal margin to costa; fore wing generally grey with complete whitish fascia and the median band uniformly coloured at least on its inner margin; a spruce feeder. . . . . **occultana** Frmn.
 Outer edge of basal patch obliterated on costal half. 15

15. Ground colour ocherous or greyish, with two blackish or dark brown spots, the inner one representing the costal portion of the median band, below which this band is reddish-brown. Banding not very distinct. Expanse 11.5–14 mm. ♂ **velutinana** (Wlk.)
 Ground colour dark brown with purplish-brown bands; hind wing light reddish. Described from Florida. . . . . **amatana** (Dyar)

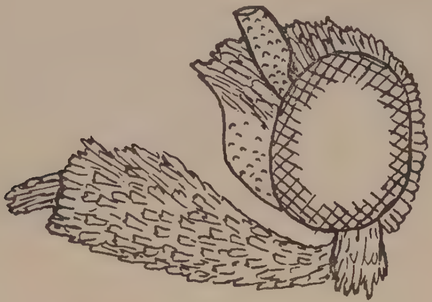


FIGURE 1. Head of *repertana* n. sp.

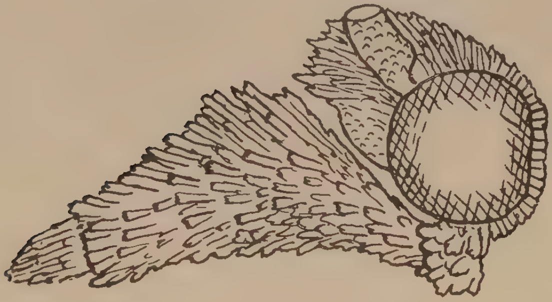


FIGURE 2. Head of *citrana* (Fern.)

Argyrotaenia velutinana (Walker)

(Pl. I, Figs. 1–6)

Cacoecia ? velutinana Walker, 1863, Cat. Lep. Het., XXVIII, 313.

Cacoecia triferana Walker, 1863, Cat. Lep. Het., XXVIII, 314.

Tortrix lutosana Clemens, 1865, Proc. Ent. Soc. Phil., V, 138; Zeller, 1876, Verh. z.-b. Ges. Wien, XXV, 225.

Tortrix incertana Clemens, 1865, Proc. Ent. Soc. Phil., V, 138; Robinson, 1868, Trans. Am. Ent. Soc., II, 278, Pl. VI, figs. 57, 58.

Tortrix velutinana (Walker), Grote and Robinson, 1868, Trans. Am. Ent. Soc., II, 83.

Lophoderus triferanus (Walker), Walsingham, 1879, Ill. Lep. Het., IV, 15, Pl. LXIII, fig. 9; Fernald, 1882, Trans. Am. Ent. Soc., X, 15.

Lophoderus velutinana (Walker), Fernald, 1882, Trans. Am. Ent. Soc., X, 16.
Eulia triferana (Walker), Dyar, 1902, List N.A. Lep., No. 5421.
Eulia velutinana (Walker), Dyar, 1902, List N. A. Lep., No. 5424; Forbes, 1923, Cornell Univ. Agri. Exp. Stat., Memoir 68, 490.
Argyrotaenia velutinana (Walker), McDunnough, 1939, Check List Lep. Can. and U.S.A. (Part 2), No. 7443.
Argyrotaenia lutosana (Clem.), McDunnough, 1939, Check List Lep. Can. and U.S.A. (Part 2), No. 7444.

Because of the sexual dimorphism of this species, Walker (1863) and Clemens (1865), working independently at about the same time, both described the male and female as distinct species. A few years later, Robinson (1868) misidentified Clemens' *lutosana* and figured as this an undescribed species to which I gave the name *occultana* Frmn. In 1879, Walsingham recognized that all the names proposed by Walker and Clemens belonged to one species. Later authors have followed either Robinson or Walsingham but a recent examination of Clemens' types shows that his names are synonymous with one another and also with Walker's names, as judged from Walsingham's depiction of Walker's species.

In the Ottawa district there are two or possibly three generations a year with the largest number of individuals flying in late May or early June and again in July. The males of the spring generation are generally darker than those emerging later in the summer, this difference not being so apparent in the females. In general the male moth is ocherous or greyish-ocherous with a rather poorly defined basal patch, usually distinct on the dorsal half only and angled outward at the fold. The median band is distinct, blackish or very dark brown on the costal half, brownish-ocherous on the dorsal half, the two halves being sharply defined. Beyond this is the usual *Argyrotaenia* costal spot followed below, or prolonged into, a brownish-ocherous spot. In the female the basal patch is further reduced to a short black spur representing the outer margin of that patch; and the whole area within, above to the costa, and outward to the inner edge of the median band is ocherous and stands out against the uniformly reddish brown median band.

Expanse: ♂, 11.5–14 mm.; ♀, 14–16.5 mm.

Type locality: North America [*velutinana* (Wlk.), *triferana* (Wlk.)]; Virginia [*lutosana* (Clem.)]; unknown [*incertana* (Clem.)].

Type: British Museum [*velutinana* (Wlk.), *triferana* (Wlk.)]; Philadelphia Academy of Natural Sciences, [*lutosana* (Clem.), *incertana* (Clem.)].

Food plant: The larva feeds generally as a leaf-tyer on almost any plant apparently, except conifers, and has been recorded, possibly in error on balsam fir.

Distribution: Que., Ont., N.Y., Mass., Penna., Mo., Tex.

Argyrotaenia repertana n. sp.

(Fig. 1; Pl. I, Figs. 7–12)

Head and thorax brownish-ocherous. Fore wing brownish-ocherous on a white ground, with darker median band and outer costal spot. Basal patch brownish-ocherous, its outer margin angled outwardly at the fold,

poorly defined throughout and extending to the costa. The area between the basal patch and the median band is concolorous with the basal patch on the costal half and becomes whitish on the dorsal half. In two of the paratypes this white area extends to the costa and in consequence the basal patch is outstanding. *Median band* oblique, reddish-brown, *containing a minute spot of white at the middle of its outer margin.* Outer costal spot concolorous with the median band, the space between brownish-ccherous. Terminal area from apex to tornus whitish. Fringe brownish-ocherous. *Hind wing white,* with slightly clouded anal area and light ocherous apex; fringe white with slightly darker basal line. Expanse of holotype, 16.5 mm. of paratypes, 15–19 mm. Moth in late May and June.

Holotype—♀, Waweig, N.B., June 15, 1938 (T. N. Freeman); No. 5408 in the Canadian National Collection, Ottawa, Ont.

Allotype—♂, St. Andrews, N.B., June 4, 1938 (T. N. Freeman).

Paratypes— 1 ♂, 4 ♀, Waweig, N.B., June 10–16, 1938 (T. N. Freeman); 1 ♂, 1 ♀, St. Andrews, N.B., June 9 and 18 (respectively) 1938 (T. N. Freeman); 1 ♀, S. Milford, N.S., June 28, 1934 (J. McDunnough); 1 ♀, White Point Beach, Queens Co., N.S., emerged in office Jan. 27, 1936 (J. McDunnough), reared from *Aralia* sp.; 1 ♀, Barrington Passage, N.S., June 19, 1910 (C. H. Young); 5 ♂, Aweme, Man., May 27, 1922 (N. Criddle); 1 ♂, Aweme, Man., June 13, 1923 (N. Criddle); 1 ♂, Saskatoon, Sask., May 31, 1924 (K. King); 2 ♂, Passadumkeag, Me., June 18, 1938 and June 2, 1935 (A. E. Brower); 3 ♂, Augusta, Me., May 30, 1940 (A. E. Brower); 1 ♂, Augusta, Me., May 17, 1491 (A. E. Brower). Paratypes in the U. S. N. M. and the collection of Dr. A. E. Brower, Augusta, Me.

This species resembles, somewhat, the females of *velutinana* (Wlk.) and might be confused with it. However it is readily separated by its larger size and mostly white hind wings.

Food plant: Aralia sp.

Distribution: N.S., N.B., Que., Man., Sask., Me.

Argyrotaenia pinatubana (Kearfott)

(Pl. I, Figs. 13–18)

Tortrix politana Haworth, Packard, 1890, Fifth Report U.S. Ent. Comm., 791 (life history).
Eulia pinatubana Kearfott, 1905, Can. Ent., XXXVII, 9; Forbes, 1923, Cornell Univ. Agri. Exp. Stat., Memoir 68, 490.
Argyrotaenia pinatubana (Kearfott), 1939, McDunnough, Check List Lep. Can. and U.S.A. (Part 2), No. 7445.

Sexes similar. Head and thorax ocherous. Abdomen grey, blackish or mouse coloured with ocherous apical tufting more noticeable on the male. Fore wing with broad well defined orange to reddish-ocherous basal patch, the outer margin of which is distinct from costa to posterior margin; median band and outer costal spot well defined and concolorous with the basal patch, the median band usually with a lighter area near the middle of its inner margin; the bands are separated by a complete fascia of whitish or light ocherous which colour predominates in the apical region. Hind wing smoky, becoming paler basally; fringe paler with darker basal line. Expanse: ♂, 13–15 mm.; ♀, 14–18 mm.

Somewhat resembles *repertana* Frmn. and the females of *velutinana* (Wlk.) but is more distinctly banded. Moth from late April to early June.

Type locality: Essex Co. Park, N.J.

Type: American Museum of Natural History.

Food Plant: the larvae feeds on Pine, binding the needles together to form a tube in which it lives. It is often injurious.

Distribution: N.S., N.B., Que., Ont., Maine, N.J., N.Y.

Remarks: The illustrated homotype was ably compared with Kearfott's type by Dr. C. V. Mitchener of the American Museum of Natural History.

Argyrotaenia occultana Freeman

(Pl. I, Figs. 19–24)

Tortrix lutosana (Clemens), Robinson, 1868, Trans. Am. Ent. Soc., II, 279, Pl. VI, fig. 59.
Argyrotaenia occultana Freeman, 1942, Can. Ent., LXXIV, 57; 1942, Brown and McGuffin, Can. Ent., LXXIV, 60 (larva).

This is the species misidentified by Robinson and figured by him as *lutosana* (Clem.). Sexes similar. A moderate sized species with dark brown basal patch, median fascia, and outer costal spot; the spaces between these areas appearing as greyish or white fascia; *outer margin of the basal patch distinct from the costa to the hind margin.* In general colour it could only be confused with the much larger *mariana* (Fern.), the separating characters being noted in the key and accompanying plate. Expanse: 17–19 mm. Moth in late June and early July.

Type locality: Mt. Lyall, Que.

Type: In the Canadian National Collection, Ottawa, Ont.

Food Plant: Spruce.

Distribution: N.S., N.B., Que., Ont., Alta., N.Y.

Argyrotaenia mariana (Fernald)

(Pl. I, Figs. 43–45)

Lophoderus mariana Fernald, 1882, Trans. Am. Ent. Soc., X, 67.
Eulia mariana (Fernald), 1902, in Dyar List N. A. Lep., No. 5427; Forbes, 1923, Cornell Univ. Agri. Exp. Stat. Memoir 68, 491.
Argyrotaenia mariana (Fernald), McDunnough, 1939, Check List Lep. Can. U.S.A. (Part 2), No. 7450.

Sexes similar. Head white, rarely grey. Thorax white or light ocherous with brown posterior crest. Abdomen whitish or grey with lighter apical tuft. Fore wing white with ocherous, brown, or black markings; basal patch mostly indistinct and indicated by a dark ocherous patch with angled black outer margin, which usually extends only to the middle of the wing and is most prominent at the hind margin; median band black, rarely brown on costal half where it often connects with the black, rarely brown outer costal spot in varying degrees of completion, below the middle the band is suddenly light brown, often indistinct along the outer margin; a light grey or light brown spot is usually present just

above the tornus; rest of the wing white, finely striated with light ocherous and with short black striae along the hind and outer margins. Fringe light ocherous. Hind wing smoky; fringe white with dark basal line. Expanse: 17–24 mm. Moth in May or June.

Type locality: Described from four males from Orono, Me., Mass., and N.Y.

Cotypes: 4♂ in the United States National Museum.

Food plants: Apple, blueberry, and possibly oak.

Distribution: N.S. to Ont., south to Fla.

Remarks: A large whitish species, with the median band and outer costal spot black, and often united to form a large black costal triangle beyond the middle. It is often a pest in apple orchards.

Argyrotaenia tabulana n. sp.

(Pl. I, Figs. 25–30)

Sexes similar. Head, palpi, and thorax, light brown. Fore wing light brownish-grey with a pinkish cast and irrorated with dark reddish-brown lines which represent the outer borders of the usual *Argyrotaenia* pattern. The basal patch is represented by two dark reddish-brown angulated lines. The oblique median band is a bit darker than the ground colour, shows a purplish cast, and is bordered outwardly and inwardly with irregular reddish-brown distinct lines. The costal spot beyond the median band is reddish-brown with darker inner and outer edges, and is contiguous or slightly remote from a similarly coloured elongate spot above the tornus. Beyond the costal spot are one or two short dark reddish-brown preapical lines from the costa; fringe light reddish-brown. Hind wing smoky, becoming lighter toward the base; fringe light with dark basal line and becoming tawny toward the apex. Underside of fore wing smoky with light ocherous costal and outer margins, and obliquely crossed with evenly spaced dark fuscous lines. Underside of hind wings white with several dark fuscous spots at the apex. Expanse of holotype, 17.5 mm., of paratypes, 13–17 mm.

This species exhibits a certain amount of variation of maculation. The ground colour varies from light brown to greyish and the median band may be represented only by the darker outer borders, or it may be considerably darker than the ground colour but with still darker distinct outer borders. The maculation of this species somewhat resembles that of *pinatubana* Kft. Moth from late April to early June.

Holotype—♀, Constance Bay, Ont., Apr. 29, 1941 (J. McDunnough); No. 5409 in the Canadian National Collection, Ottawa.

Allotype—♂, Kazubazua, Que., June 7, 1927 (F. P. Ide).

Paratypes—3 ♂, Biscotasing, Ont., June 6, 11, 1931 (Karl Schedl); 2 ♀, Kazubazua, Que., June 11, 1935 (G. S. Walley); 1 ♀, Hawk Lake, Ont. Reared on Jack Pine by the Forest Insect Survey and emerged in incubator Jan. 29, 1941; 2 ♂, 2 ♀, Peachland, B.C., May 23, 1936 (A. N. Gartrell); 1 ♀, Jesmond, B.C., bred from *Pinus contorta* and emerged

in laboratory Feb. 16, 1936 (J. K. Jacob); 1 ♀, Baynes Lake, B.C., reared on *Pinus ponderosa* Dougl. and emerged in incubator Feb. 9, 1942. Paratypes in the U.S.N.M.

Food plant: Pine.

Distribution: Que., Ont., Man., B.C.

Remarks: Mines Jack Pine needles, webbing two needles together and eating out the inside of one needle very thoroughly causing the needle to appear cream coloured and making it very conspicuous.

Argyrotaenia citrana (Fernald)

(Fig. 2; Pl. I, Figs. 31–36)

Tortrix citrana Fernald, 1889, Ent. Amer., V, 18.
Argyrotaenia (Tortrix) citrana (Fernald), Basinger, 1935, Cal. Agr. Mo. Bull., XXIV, 233.
Tortrix citrana Fernald, McDunnough, 1939, Check List Lep. Can. U.S.A. (Part 2), 57, No. 7414.

A variable species with acute apex of fore wing. Ground colour of fore wing grey, reddish-brown or ocherous; basal patch darker than ground colour or absent; oblique median band blackish or dark brown, narrower on costal third and fading out on its outer edge posteriorly; outer costal spot distinct or absent. Fringe light to dark ocherous. Hind wing white with a few short, dark, striae, more noticeable on outer half; fringe whitish, sometimes with darker basal line. Labial palpi with second joint tufted on upper side (fig. 2) and broadest at the middle giving it a triangular lateral aspect. Expanse: ♂, ♀, 14–19 mm. Moth intermittently throughout the year.

Type locality: California.

Type: A ♀ in the United States National Museum.

Food plants: Orange and other citrus fruits, Solidago, willow, Geranium, rose and Asparagus. Apparently a general feeder.

Distribution: Calif., north in greenhouses to B.C.

Remarks: A pest of considerable economic importance to the citrus fruits of California, and in greenhouses in British Columbia. It is the only species studied in the genus which possesses a triangular second palpal joint.

Argyrotaenia niscana (Kearfott)

(Pl. I, Figs. 37–38)

Eulia niscana Kearfott, 1907, Trans. Amer. Ent. Soc., XXXIX, 94.
Eulia camerata Meyrick, 1912, Ent. Mon. Mag., XLVIII, 35.
Argyrotaenia niscana (Kearfott), McDunnough, 1939, Check List Lep. Can. U.S.A. (Part 2), No. 7449.

Sexes similar. Head and thorax rust coloured. Abdomen grey-brown. Fore wing rust coloured with narrow, white fasciae and streaks; basal patch rust coloured, wide, its oblique outer margin slightly irregular and well defined from costa to hind margin; beyond the basal patch is a narrow silvery-white complete fascia, often outlined in part with black; beyond, the

wing is rust coloured with a short silvery-white costal streak just beyond the middle, its posterior end curved abruptly outward and broken to include a round black dot, or continued to the tornus; near the apex of the costa, is a short white streak, and still nearer the apex is a light ocherous streak (sometimes broken) extending almost to the light ocherous tornal region; fringe light ocherous or tawny, darker at the apex. Hind wing entirely dark smoky, slightly striated with a darker shade; fringe lighter with dark basal line. Expanse: 15 to 18 mm. Moth from May to July.

Type locality: Carmel, Calif.

Type: ♂ in the American Museum of Natural History.

Food plant: Unknown.

Distribution: Calif.

Remarks: Easily distinguished by its rust-red colour and outstanding silvery-white costal streaks.

Argyrotaenia coloradana (Fernald)

(Pl. I, Fig. 39)

Lophoderus coloradana Fernald, 1882, Trans. Am. Ent. Soc., X, 67.
Eulia coloradana (Fernald), 1903, in Dyar List N. A. Lep., 485, No. 5425.
Argyrotaenia coloradana (Fernald), McDunnough, 1939, Check List Lep. Can. U.S.A. (Part 2), No. 7447.

Sexes apparently similar. Head and abdomen light ocherous. Thorax reddish-brown. Fore wing with broad, well defined, reddish-ocherous basal patch, the outer margin of the latter distinct from the costa to the posterior margin of the wing; median band distinctly reddish-brown, darker on the costa, becoming lighter behind, its inner margin narrowly but distinctly outlined with yellow, and deeply indented just below the radial vein; outer costal spot large, deep reddish-brown, contrasting with the white costal area on either side; between the bands and in the apical region of the wing the white ground colour is obscured by streaks and patches of light ocherous; fringe light ocherous with white rays. Hind wing white, with smoky anal region which may easily be erased in spreading, or in poor specimens; fringe white. Expanse: 21–26 mm. Moth in July.

Type locality: Colorado.

Cotypes: 1 ♂, 1 ♀, in the United States National Museum.

Food plant: Unknown.

Distribution: Colo., Utah.

Remarks: Easily recognized by the distinct reddish-brown outer costal spot which contrasts with the white ground surrounding it. Somewhat resembles *Archips argyrospila* Wlk. but the latter has the hind wings entirely smoky.

Argyrotaenia quadrifasciana (Fernald)

(Pl. I, Figs. 40–42)

Lophoderus quadrifasciana Fernald, 1882, Trans. Am. Ent. Soc., X, 67.
Eulia quadrifasciana (Fernald), 1902, Fernald in Dyar List N. A. Lep., No. 5419; Forbes, 1923, Cornell Univ. Agri. Exp. Stat., Memoir 68, 491.
Argyrotaenia quadrifasciana (Fernald), McDunnough, 1939, Check List Lep. Can. U.S.A. (Part 2), No. 7453.

Sexes dimorphic. *Male:* Head, thorax and fore wing yellow, the latter uniformly reticulate with orange and crossed by an antimedian and postmedian narrow, complete, purplish-brown (rarely orange) fascia; apical region suffused with purplish-brown; fringe light ocherous, dark in tornal region. Hind wing dark fuscous; fringe light fuscous with darker basal line. *Female:* Like the male except the bands are orange (rarely purplish), apical region of fore wing reticulated with orange and hind wings brownish-orange. Fringes as in male. Expanse: ♂, 15–18 mm.; ♀, 17–19 mm. Moth in June and July.

Type localities: Me., N.H., Mass., N.Y., Ill.

Cotypes: 2 ♂, 1 ♀, in the United States National Museum.

Food plants: Crataegus, Amelanchier.

Distribution: P.E.I. to Ont., south to Penn. and Mo.

Remarks: Easily distinguished by its orange-yellow colour with orange or purplish-brown bands.

Argyrotaenia quercifoliana (Fitch)

(Pl. I, Figs. 46–49)

Argyrolepia quercifoliana Fitch, 1858, Trans. N.Y. State Agr. Soc., XVIII, 826. (Reprinted 1859, Fifth Rept. Noxious Insects N.Y., 46).
Tortrix (Argyrotoxa) trifurculana (Zeller), 1875, Verh. Zool.-bot. Ges. Wien, XXV, 226.
Tortrix quercifoliana (Fitch), Fernald, 1902, in Dyar List N. A. Lep., No. 5399.
Eulia quercifoliana (Fitch), Forbes, 1923, Cornell Univ. Agri. Exp. Stat., Memoir 68, 491.
Argyrotaenia quercifoliana (Fitch), McDunnough, 1939, Check List Lep. Can. U.S.A. (Part 2), No. 7452.

Sexes similar. Creamy-yellow, finely dotted with light brown; two narrow, darker brown, oblique fascia, the post median one forked at the costa, and connected near its middle to a curved, subterminal, dark brown fascia, also forked on the costa just before the apex; fringe white or yellowish with darker basal line. Hind wing and fringe pure shining white. Expanse: ♂, 16–20, mm., ♀, 19–24 mm. Moth in June and July.

Type locality: New York?

Type: A ♂ without abdomen in the United States National Museum.

Food plants: Oak, buckthorn and witch-hazel.

Distribution: Que. to Man. south to Tex. and Fla.

Remarks: Some specimens (fig. 46) possess a light brown blotch near the middle of the fore wing and thus resemble *alisellana* (Rob.). However, the numerous light brown dashes in the basal and terminal areas of *quercifoliana* readily distinguish this species. Individuals rarely occur which are almost entirely light cream coloured, the brown maculation being obliterated.

Argyrotaenia juglandana (Fernald)

(Pl. I, Figs. 50–53)

Tortrix (Lophoderus) juglandana Fernald, 1879, Can. Ent., XI, 155.

Eulia juglandana (Fernald), Fernald, 1902, in Dyar List N.A. Lep., No. 5420; Forbes, 1923, Cornell Univ. Agri, Exp. Stat., Memoir 68, 491.

Argyrotaenia juglandana (Fernald), McDunnough, 1939, Check List Lep. Can. U.S.A. (Part 2), No. 7454.

Sexes quite similar. *Male:* Fore wing brown, inclined to be speckled and crossed by two narrow, dark brown, oblique fascia which are wider on the costa. Fringe dark brown to blackish, becoming light toward the apex. Hind wing and fringe, shining fuscous. Female darker brown than the male with no speckled appearance. Expanse: ♂, 17–19 mm., ♀, 21–26 mm. Moth in June and July.

Type locality: Described from 11 males and 15 females from the following localities: Mass., N.Y., Ont., Ohio, Wis. Part of the type series was reared from Hickory by J. Angus of West Farms, N.Y.

Cotypes: 3 ♂, 3 ♀, in the United States National Museum.

Food Plant: Hickory, also recorded on *Viburnum.*

Remarks: This is the largest species in the genus. Full grown larvae occur in a longitudinally rolled hickory leaf in the latter half of June and pupate beneath the bark along the trunk of the tree.

Distribution: Que. to Ont. south to Penna. and Minn.

Argyrotaenia amatana (Dyar)

(Pl. I, Fig. 54)

Lopgoderus amatana Dyar, 1901, Jour. N.Y. Ent. Soc., IX, 24.

Eulia amatana (Dyar), Fernald, 1902, in Dyar List N.A. Lep., 485, No. 5422.

Argyrotaenia amatana (Dyar), McDunnough, 1939, Check List Lep. Can. U.S.A. (Part 2), 58, No. 7446.

Head and thorax reddish-brown. Fore wing brownish-orange with purple-brown basal patch, median band and outer costal spot, the first not reaching the costa; terminal space whitish. Hind wing orange, fading basally and of the same colour as that of the hind wing of the female of *quadrifasciana* Fern.

This species is easily recognized by the orange brown colour of both fore and hind wings and in size approaches *velutinana* Wlk. Expanse: ♂, 13 mm., ♀, 18–19 mm.

Type locality: Palm Beach, Florida.

Type: United States National Museum.

Food plants: Recorded by Dyar, 1901, op. cit., as bred from *Annona glabra* Linn. = *laurifolia* Duval. and, *Nectandra coriacea* (Sw.) Griseb. = *Wildenoviana* Nees. Also avocado (U.S.N.M. record). According to Dyar the larvae ties up the leaves with a series of transverse walls of web, leaving a round hole in each web near the leaf for the larva to pass through.

Distribution: Florida.

The only specimen the author has of this species is a rather worn male from Perrime, Florida, June 8, 1923, G. F. Moznette Coll., reared from avocado and kindly loaned for study by the authorities of U.S.N.M. through Mr. Carl Heinrich.

Argyrotaenia alisellana (Robinson)

(Pl. I, Figs. 55–56)

Tortrix alisellana Robinson, 1869, Trans. Am. Ent. Soc., II, 267, Pl. I, fig. 15.
Eulia alisellana (Robinson), Fernald, 1902, in Dyar List N. A. Lep., No. 5428; Holland, 1913, Moth Book, 423, Pl. XLVIII, fig. 39; Forbes, 1923, Cornell Univ. Agri. Exp. Stat., Memoir 68, 491.
Argyrotaenia alisellana (Robinson), McDunnough, 1939, Check List Lep. Can. and U.S.A. (Part 2), No. 7451.

Sexes similar. Head and thorax white. Fore wing light brown with white or cream coloured basal third, which sometimes contains a few light brown scales, and with marginal, pure white or cream coloured, rounded blotches as follows: One at the middle of the costa, one at the costal four-fifths, one at the middle of the outer margin, and one smaller one just before the tornus on the hind margin. Hind wing white. Fringes white. Expanse: 18–24 mm. Moth in June and July.

Type locality: Ohio.

Type: Probably lost.

Food plant: Unknown.

Distribution: Que., Ont., N.Y., Ohio, Penna., Ind., Ill., and Va.

Argyrotaenia gloverana (Walsingham)

Lophoderus gloveranus Walsingham, 1879, Ill. Lep. Het. B.M., 14, Pl. LXIII, fig. 7.
Eulia gloverana (Walsingham), 1903, Fernald, in Dyar List N. A. Lep., 485, No. 5425.
Argyrotaenia gloverana (Walsingham), 1939, McDunnough, Check List Lep. Can. U.S.A. (Part 2), 58, No. 7448.

Very little appears to be known about this Californian insect and it is absent from most collections. The author has never seen it, his key characters being based entirely upon the original description and figure, the former of which reads as follows: "Head whitish grey, thickly clothed above and in front; palpi whitish grey, brownish at the sides, projecting the length of the head beyond it: antennae slightly pubescent: thorax

with a raised ferruginous tuft of scales at the back; patagia of the same colour. Fore wings—with the costa arched; apical margin very oblique, slightly emarginate below the apex—rather shining leaden grey, with a ferruginous patch at the base extending over one fourth of the wing, externally margined with brownish fuscous; an irregular, waved, greyish-fuscous fascia about the middle, clearly defined only on its inner edge; beyond and before it are some transverse streaks and lines of brownish fuscous, especially towards the apex; the apical portion of the costa clothed with brownish fuscous, and some streaks of the same colour running through the grey cilia. Hind wings pale brownish fuscous; cilia paler, 1 ♂. Expanse of wings 19 millims."

"Near Mount Shasta, California, Sept. 3rd, 1871."

Type: British Museum.

Food plant: Unknown.

EXPLANATION OF PLATE I (*See opposite page*)

1. *A. velutinana* (Wlk.), ♂, Constance Bay, Ont., (agrees with ♂ type *lutosana* Clem.).
2. *A. velutinana* (Wlk.), ♂, Mer Bleue, Ont.
3. *A. velutinana* (Wlk.), ♂, Ottawa, Ont.
4. *A. velutinana* (Wlk.), ♀, Meach Lake, Que.

5, 6. *A. velutinana* (Wlk.), ♀'s, Ottawa, Ont.

7. *A. repertana* n. sp., ♀, holotype, Waweig, N.B.
8. *A. repertana* n. sp., ♂, paratype, Augusta, Maine.
9. *A. repertana* n. sp., ♂, paratype, Aweme, Man.
10. *A. repertana* n. sp., ♂, allotype, St. Andrews, N.B.
11. *A. repertana* n. sp., ♀, paratype, White Pt. Beach, N.S.
12. *A. repertana* n. sp., ♀, paratype, Barrington Passage, N.S.
13. *A. pinatubana* (Kft.), ♂, Chelsea, Que., homotype (Mitchener, 1943).
14. *A. pinatubana* (Kft.), ♂, Wright, Que.
15. *A. pinatubana* (Kft.) ♂, Chelsea, Que.
16. *A. pinatubana* (Kft.), ♀, S. Milford, N.S.
17. *A. pinatubana* (Kft.), ♀ Tabusintac, N.B.
18. *A. pinatubana* (Kft.), ♀, Ottawa, Ont.
19. *A. occultana* Frmn., ♂, holotype, Mt. Lyall, Que.
20. *A. occultana* Frmn., ♂, Mt. Laurier, Que.
21. *A. occultana* Frmn., ♂, paratype, Mer Bleue, Ont.
22. *A. occultnaa* Frmn., ♀, allotype, Mt. Lyall, Que.
23. *A. occultana* Frmn., ♀, paratype, Burbidge, Que.
24. *A. occultana* Frmn., ♀, paratype, McAdam, N.B.
25. *A. tabulana* n. sp., ♀, holotype, Constance Bay, Ont.

26,27. *A. tabulana* n. sp., ♂♂, paratypes, Biscotasing, Ont.

28. *A. tabulana* n. sp., ♂, allotype, Kazabuzua, Que.

29,30. *A. tabulana* n. sp., ♀♀, paratypes, Peachland, B.C.

31. *A. citrana* (Fern.), ♂, Riverside, Calif.

32,33. *A. citrana* (Fern.), ♂♂, Victoria, B.C.

34,36. *A. citrana* (Fern.), ♀♀, Ladysmith, B.C.

35. *A. citrana* (Fern.), ♀, Victoria, B.C.

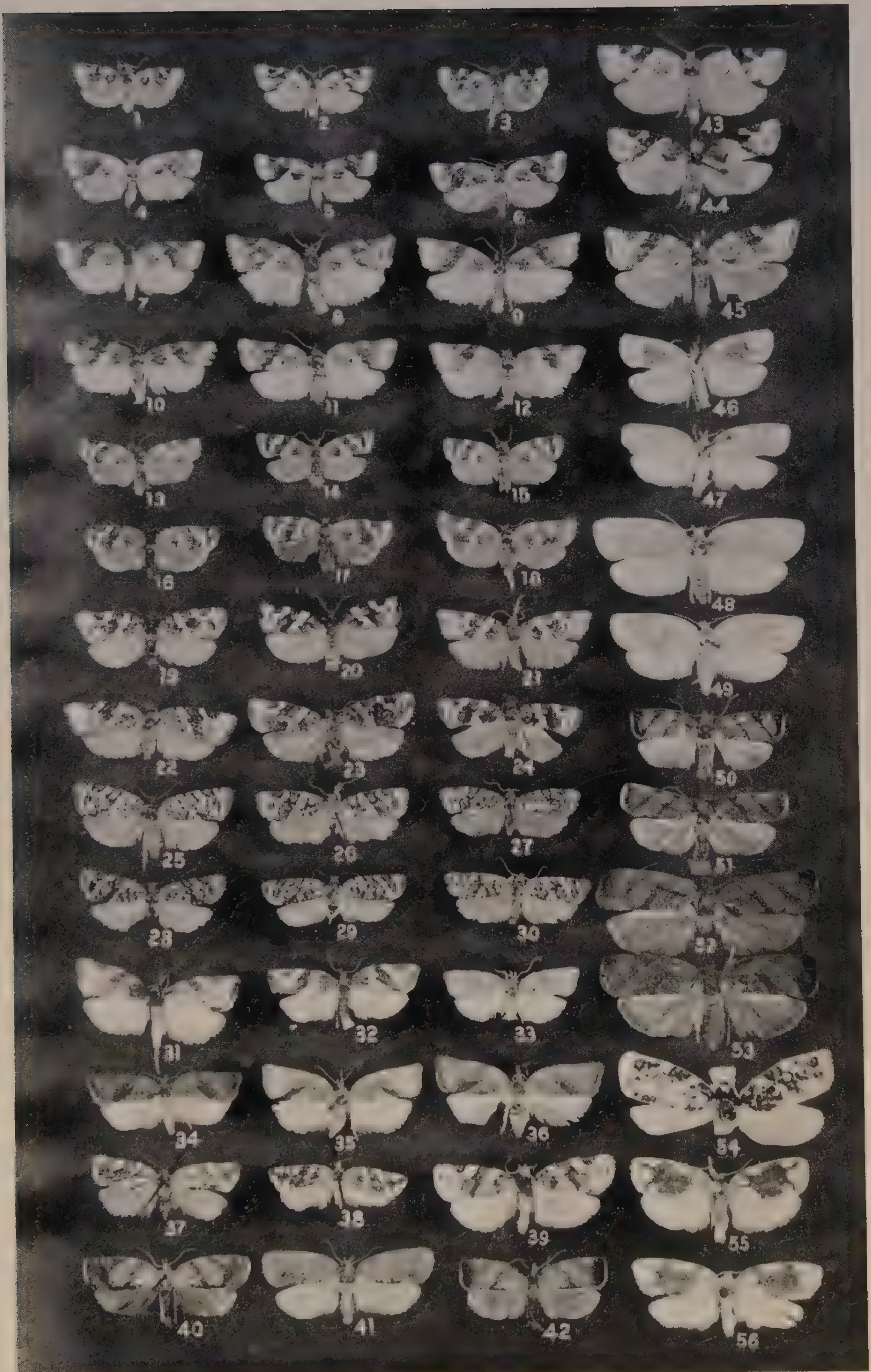
37,38. *A. niscana* (Kft.), ♀♀, Cajon Valley, Calif.

39. *A. coloradana* (Fern.), ♂, Estes Park, Colo.
40. *A. quadrifasciana* (Fern.), ♂, Norway Bay, Que.
41. *A. quadrifasciana* (Fern.), ♀, Meach Lake, Que.
42. *A. quadrifasciana* (Fern.), ♂, Bobcaygeon, Ont.
43. *A. mariana* (Fern.), ♂, Ottawa, Ont.
44. *A. mariana* (Fern.), ♂, Berwick, N.S.
45. *A. mariana* (Fern.), ♀, Annapolis Royal, N.S.
46. *A. quercifoliana* (Fitch), ♂, Aweme, Man.
47. *A. quercifoliana* (Fitch), ♀, Simcoe, Ont.
48. *A. quercifoliana* (Fitch), ♀, Meach Lake, Que.
49. *A. quercifoliana* (Fitch), ♀, Ottawa, Ont.

50-53. *A. juglandana* (Fern), ♂♂, ♀♀, Simcoe, Ont.

54. *A. amatana* (Dyar), ♀, Perrime, Fla. (From Photo)

55,56. *A. alisellana* (Rob.), ♂♂, Mt. Lake, Va.



(*Photo by Marier*)

BOOK REVIEW

A SOURCE BOOK OF AGRICULTURAL CHEMISTRY by Charles A. Browne, Bureau of Agricultural and Industrial Chemistry, U.S. Department of Agriculture; 250 pages, cost $5.00. Published by Chronica Botanica Co., Waltham, Mass., U.S.A.; Canadian Agents, Wm. Dawson Subscription Service Ltd., Toronto, 2, Ont.

The author devoted upwards of forty-five years to the field of Agricultural Chemistry where his duties consisted of teaching and research for industrial organizations, educational institutions and the U.S.D.A. About two decades of this time was spent as chief chemist and supervisor of agricultural research for the Bureau of Chemistry and Soils, from which he retired in 1940. As a result of long years of experience, he is eminently qualified to write a book on Agricultural Chemistry. The following statement in the preface gives Dr. Browne's reason for the book and his treatment of the subject matter: "The purpose of the author in writing the present work has been to give a more accurate and complete account, than has hitherto appeared, of the origins of agricultural chemistry and of the relationships of Liebig's work to that of his predecessors. In doing this he has preferred so far as possible to let these predecessors in selected passages give their own accounts of the work selected for description, with no attempts at modernization of language. This volume is therefore primarily a source-book and while there can be a just difference of opinion in the choice of selective material, it is hoped that the various quotations and translations submitted will give the reader a good general perspective of developments in the history of agricultural chemistry from early beginnings down to the time of Liebig. Unless otherwise stated the various translations of original source material were made by the author."

The book consists of an introduction in which the author defines Agricultural Chemistry. This is followed by seven chapters beginning with Agricultural Chemistry in ancient times (early Greek period 1940 B.C. —79 A.D., Thales to Pliny) and tracing this development through the early Royal Society period (Boyle to Tull); through the period of the alchemists; the early and late Phlogiston periods; the period from Lavoisier to DeCandolle and on to include Liebig.

The book is well indexed both as to subjects and authors. It is by no means a text book on, nor is it a complete history of the development of Agricultural Chemistry. However, it is an excellent reference for both student and instructor interested in the part chemistry has played in the scientific explanation and development of agriculture. Dr. Browne has brought together under the covers of this book many of the important original investigations and the theories which have influenced our present conceptions regarding the importance of proper food and protection for both the plant and animal kingdoms. He has presented the theories of the various authors referred to and some of their controversies without any conscious attempt on his part to influence the reader.

Many of the original papers and books reviewed by the author are available only in the larger and better equipped libraries, and not a few of us welcome the opportunity of placing copies of *A Source Book of Agricultural Chemistry* in our libraries and on our reference shelves.

F. A. WYATT.

HISTORY, DESCRIPTION, DISTRIBUTION AND PERFORMANCE OF AJAX AND EXETER OATS[1]

J. N. WELSH[3]

Dominion Laboratory of Cereal Breeding, Winnipeg, Man.

[Received for publication September 15, 1944]

INTRODUCTION

Previous to 1935, the varieties of oats grown in Canada were susceptible to many diseases such as stem rust, crown rust, loose and covered smut, and halo-blight. The only exceptions were Anthony and Green Russian, two varieties originating in the United States, which were resistant to certain races of stem rust, and grown to a limited extent in Manitoba.

In 1935, the Ontario Agricultural College, Guelph, released Erban, a variety that is resistant to both smuts and moderately resistant to certain races of crown rust in the mature plant stage. It is grown extensively in Eastern Canada, particularly in areas where crown rust is usually prevalent. In 1936, the Dominion Laboratory of Cereal Breeding, Winnipeg, distributed Vanguard which is resistant to the races of stem rust that commonly occur in Canada. It is widely grown in Manitoba and to a considerable extent in Saskatchewan and Alberta, as well as in certain areas of Ontario and Quebec that are subject to damage from stem rust. Both Erban and Vanguard are medium early maturing varieties. As earlier maturing varieties are more suitable in some areas and later maturing ones in others, there is a need of disease resistant varieties with these characteristics. To meet this need, two new varieties, Ajax and Exeter, were distributed by the Dominion Laboratory of Cereal Breeding, Winnipeg. The purpose of the present paper is to give the history, description and performance of these two varieties.

HISTORY

Ajax, R.L. 1114, C. A. N. 660, came from a cross made in 1930 at the Dominion Laboratory of Cereal Breeding, Winnipeg, between Victory and the stem rust resistant variety Hajira. Continuous plant selection was practised with this cross until 1936, at which time the plants had reached the sixth generation. Numerous lines were increased in 1937 and the most promising of these were given a yield test at Winnipeg in 1938. R.L. 1114 (Ajax) was the most outstanding and was placed in the Co-operative Rod Row Tests in 1939. It performed exceptionally well, both in 1939 and in 1940, and on the basis of these tests was accepted for registration in 1941.

Exeter, R.L. 53, C. A. N. 661, came from a cross made in 1929 at the Dominion Laboratory of Cereal Breeding, between Victory and Rusota. The latter parent is one of the Green Russian selections made and named at the North Dakota Experiment Station and is resistant to the common races of stem rust. Each stem rust resistant line of this cross was bulked separately in the F_3 and given a yield test for three years. Selections were then made from the highest yielding ones and a number of them were

[1] Contribution, number 131, from the Cereal Division, Experimental Farms Service, Department of Agriculture, Ottawa, Canada.
Paper read before the Western Canadian Society of Agronomy at Saskatoon, Sask., June 22 and 23, 1944.
[3] Senior Assistant Agricultural Scientist.

placed in a rod row test at Winnipeg in 1937. A few of the most promising lines were placed in the Co-operative Rod Row Tests in 1938 and R.L. 53 (Exeter) which was one of the highest yielding lines in these tests was accepted for registration in 1941.

DESCRIPTION

Ajax

This variety has a spreading type of panicle with the branches more acute than in many other varieties. (Figure 1.) It is comparatively short and compact and when viewed from certain angles in the field appears to be

FIGURE 1. Panicle of Ajax oats

partially unilateral, due to the fact that the uppermost spikelets tend to form in a cluster. The kernels are white and medium in size with the awns fairly numerous. The number of veins on the glumes range from 7 to 11, 9 being the predominating number. The nodes are glabrous and according to Ridgway's Colour Standard[3] the under side of the leaves are classified as Varley Green and the upper side as Deep Dull Yellow Green. It is an early maturing variety, a week to ten days earlier than Victory, and has good length and strength of straw. Because of its strength it is a suitable variety for sowing on summerfallow, but under conditions of rank growth some lodging is to be expected. To offset this, heavier rates of seeding, 2½ to 3 bushels per acre, are recommended for summerfallow. In disease reaction it is resistant to the common races of stem rust, being similar to

[3] Ridgway, Robert. Colour standards and colour nomenclature. 43 pp. Hoen & Co., Baltimore. 1912.

Vanguard and Exeter in this respect, but differs from these varieties in that it is more susceptible to the less prevalent ones. It is moderately resistant to crown rust in the mature stage, and has quite a high degree of resistance to loose and covered smut, and to halo-blight.

Exeter

This variety has a spreading type of panicle somewhat similar to Victory. (Figure 2.) It has fewer awns than Ajax and the number of veins in the glumes range from 9 to 11, with the greater majority of them having 9 veins. The kernels are white and although they are not quite as large as

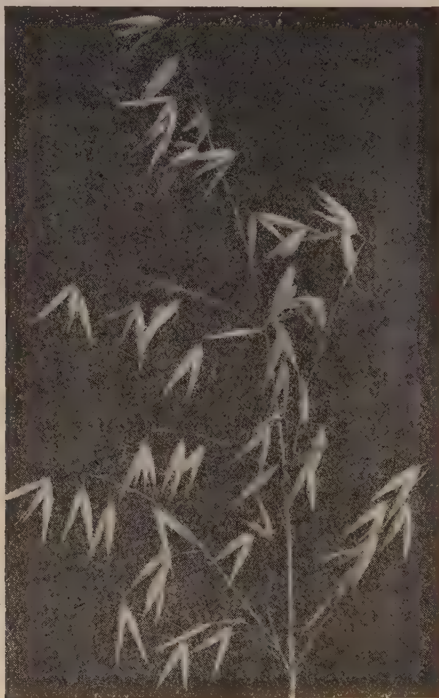


FIGURE 2. Panicle of Exeter oats

those of Victory, they resemble that variety in shape and plumpness. The nodes are glabrous and the colour of the leaves is identical with that of Ajax. It is a medium late maturing variety, being approximately two days earlier and two inches shorter in the straw than Victory. Exeter is similar to Victory in strength of straw, but since it is not considered to be a strong-strawed variety it will not stand up on fallow as well as stronger varieties such as Ajax. In general, it is recommended for those areas where stem rust is likely to occur and where the later maturing varieties are better adapted. It is resistant to the common races of stem rust and has considerable resistance to halo-blight, but is susceptible to other diseases.

DISTRIBUTION OF SEED

The method used in distributing seed of Ajax to farmers was to supply members of the Canadian Seed Growers' Association with Foundation Stock and to retain control of the produce by means of contracts. Orders

were taken for the seed and passed on to the growers most conveniently situated to make deliveries. Foundation Stock was distributed to seed growers in the winter of 1941-42 and a general distribution of 15,824 bushels was made in the winter of 1942-43. The classification of this amount into seed grades and amounts distributed in each province is given in Table 1.

During the season of 1943 it was estimated that between 500,000 and 600,000 bushels of Ajax oats were produced in Western Canada. The indications are that the greater portion of this was used for seed in 1944. As a consequence the variety is very rapidly becoming of major importance in the oat production of Western Canada.

Foundation Stock of Exeter oats was supplied to seed growers in the winter of 1941-42 in small quantities. This stock which was handled by three seed growers was increased to 3,500 bushels by the end of the 1943 season and was distributed to farmers following the same plan as with Ajax. Table 2 gives details of the distribution.

TABLE 1.—NUMBER OF BUSHELS OF REGISTERED, CERTIFIED, AND COMMERCIAL SEED OF AJAX DISTRIBUTED THROUGHOUT SIX PROVINCES DURING THE WINTER OF 1942-43

Grade	Provinces						Total
	Quebec	Ontario	Manitoba	Saskatchewan	Alberta	British Columbia	
Registered	3	125	5618	4480	471	12	10,709
Certified	—	87	2121	1971*	729	12	4,920
Commercial	—	—	87	108	—	—	195
Total	3	212	7826	6559	1200	24	15,824

* 1110 bushels were distributed by the Swift Current Experimental Station.

TABLE 2.—NUMBER OF BUSHELS OF REGISTERED CERTIFIED AND COMMERCIAL SEED OF EXETER DISTRIBUTED THROUGHOUT FOUR PROVINCES DURING THE WINTER OF 1943-1944

Grade	Provinces				Total
	Ontario	Manitoba	Saskatchewan	Alberta	
Registered	12	1329	1032	36	2409
Certified	—	381	168	—	549
Commercial	—	314	219	18	551
Total	12	2024	1419	54	3509

AGRONOMIC DATA

The agronomic data are discussed under two main headings: Controlled Plot Experiments, in which Ajax and Exeter are compared with other varieties in tests throughout Canada, and Performance of Ajax Under Farm Conditions, which summarizes the results obtained from questionnaires sent out to all farmers receiving seed of Ajax in 1943.

Controlled Plot Experiments

These data were obtained from the annual reports, sent to the Cereal Division, Central Experimental Farm, Ottawa, by all the Experimental Farms and Stations in Canada and from annual reports at the Dominion Laboratory of Cereal Breeding, Winnipeg, for periods ranging from one to four years, as well as from reports on co-operative tests conducted by the Ontario Agricultural College, Guelph, in western Ontario at 33 testing points in 1942 and 28 in 1943. The data are given in Tables 3 and 4.

Table 3 summarizes the general plant characteristics of Ajax and Exeter and certain other varieties. Since conditions vary in the different parts of Canada the data were classified separately for the Maritime Provinces, Ontario and Quebec, the Prairie Provinces, and British Columbia.

Ajax matures approximately 10 days earlier than Victory in the Maritime Provinces and British Columbia and about 7 days earlier in other parts of Canada. It shows good length and strength of straw in all areas, and is comparatively high in bushel weight except in the Maritime Provinces where it is considerably lower than Exeter or Victory, but equal to Erban. It is lower in hull content in the Prairie Provinces than in Ontario and Quebec, but the data for the former are for more than one year at a number of stations, whereas those for the latter are for one year at Lennoxville. In disease reaction it is resistant to the common races of stem rust, moderately resistant to crown rust, and has a fairly high degree of resistance to both smuts, and to halo-blight.

Exeter is 2 to 3 days earlier maturing than Victory in most areas and although the data for British Columbia indicate that Exeter is a week earlier than Victory, the difference between the two varieties is the same at Agassiz as in other parts of Canada, whereas at Saanichton, it is 12 days earlier than Victory over a 3-year period. Exeter has a slightly shorter straw than Victory and except in the Prairie Provinces it appears to be shorter than Ajax. It is quite similar to Victory in strength of straw, but slightly lower than that variety in bushel weight and weight per one thousand kernels. It is resistant to the common races of stem rust and moderately resistant to halo-blight, but is susceptible to crown rust, and although it is classed as a smut susceptible variety, it is less susceptible than Vanguard.

Table 4 gives the yields of Ajax and Exeter in comparison with other varieties in tests conducted by the Dominion Experimental Farms and Stations in Eastern and Western Canada and in co-operative tests conducted by the Ontario Agricultural College in western Ontario for periods ranging from one to four years.

In Eastern Canada Ajax yielded well in comparison with other varieties at all stations with the exception of Charlottetown and L'Assomption, while at Ste. Anne de la Pocatiere, Roxton was higher yielding than Ajax on clay land but lower yielding on sandy land over a 3-year period. Exeter, although it was not tested at all stations, yielded well in the Maritime Provinces and at Lennoxville.

In Western Canada Ajax yielded particularly well at Winnipeg, Morden, Brandon, and Scott, and although it produced lower yields than some of the later maturing varieties at all of the other stations, it yielded

well in comparison with other early maturing varieties. Although Exeter was lower yielding than Ajax at the three stations in Manitoba, it was higher yielding than the other varieties in the tests. In Saskatchewan it was the highest yielding variety at three stations and yielded equally as well as Ajax at Scott, while in Alberta it was the highest yielding variety on the average for two years at Lacombe and yielded comparatively well at the other three stations. In British Columbia it produced high yields at Agassiz and Prince George, but it does not appear to be suited to the conditions at Saanichton where the earlier maturing varieties appear to be better adapted.

Performance of Ajax Under Farm Conditions

Questionnaires were sent out to all those receiving seed of Ajax in 1943. One thousand and fifty were returned, 490 from Manitoba, 425 from Saskatchewan, 114 from Alberta, 21 from western Ontario, and 2 from Armstrong in British Columbia. The information received was summarized by provinces with each of the three prairie provinces being roughly divided into northern, central, and southern zones. The data for the prairie provinces and western Ontario are given in Table 5 and are discussed under the following headings: Suitability for Area, Strength of Straw, Yield, Time of Maturity, Stem Rust Reaction, Shattering, Feed Value of Straw, and Suggested Improvements.

The information received from British Columbia is not included in Table 5 as the number of growers reporting is too few. However, one grower considered Ajax suitable, but preferred a larger kernel and the other thought that owing to its earliness it would be desirable under certain conditions.

Adaptability—Ajax appears to be a widely adaptable variety as in all areas of each province the greater percentage of the growers considered it to be satisfactory for their district. A number, however, were undecided and a few considered it unsuitable, due mainly to its small kernel and in some instances on account of low yield and weakness of straw.

Strength of Straw—In all provinces the greater percentage of growers observed Ajax to have a stronger straw than that of the other variety grown on the farm, although a number found it to be equal in strength, and a few weaker. In all areas of Manitboa, Vanguard was the variety most commonly grown, along with some Victory, Banner, Anthony, Green Russian, and Gopher. In northern Saskatchewan, Victory appears to be the predominating variety, with some Banner, Anthony, Legacy, Vanguard, Eagle, Gopher, and Valor. In the central and southern areas, Vanguard as well as some of the other above mentioned varieties, is grown to a considerable extent. In Alberta the varieties commonly grown in all areas appear to be Victory, Banner, Eagle, and Legacy, while in Ontario, although only a few gave the name of the variety commonly grown, Vanguard was the only variety mentioned.

Yield—In the majority of cases, those sending in questionnaires gave the yield of Ajax as well as that of the main crop. They were not always comparable, however, as in the majority of cases Ajax was grown on breaking or fallow and the main crop on second crop land, under which

conditions it would naturally yield comparatively well. Furthermore, as it was sown in lots of only 3, 6, or 9 bushels, the acreage was small. However, the greater majority of the farmers considered the yield to be satisfactory with only a few finding it to be low yielding.

Thirty-eight farmers stated that Ajax was grown under the same conditions as the main crop, 10 in Manitoba, 34 in Saskatchewan, and 4 in Alberta and although the numbers are small the results are considered to be of interest as well as indicative. Fifteen farmers in Ontario gave the yields obtained with Ajax as well as that of the main crop and although it is not known if they were grown under the same conditions, the results were also thought to be of interest.

On the 10 farms in Manitoba in which Ajax was grown under the same conditions as the main crop, it yielded considerably higher than other varieties. On 5 of the farms they were sown on fallow and on the other 5 farms on second crop land. In the northern and southern parts of Saskatchewan Ajax gave higher yields than the other varieties on the average for all farms, and was only lower yielding on 1 farm in each area. In the central area, however, there was little difference between the average yield of Ajax and that of the other varieties, although on 5 of the 8 farms it gave higher yields. The yields for Alberta are for only 4 farms, but on 3 of them Ajax yielded considerably higher than the other varieties, while on the fourth farm, at Innisfail, it yielded the same as Legacy. Of the 21 growers reporting from Ontario, which included farms in the Rainy River District to as far east as Bowmanville, all but 3, who were undecided, were satisfied with the yield of Ajax.

In all provinces there were districts in which the growing season was unfavourable. In some the season was late due to spring rains and in others it was quite dry. Ajax apparently did well, for the most part, when sown late, and in the drier areas the majority thought it had more drought resistance than other varieties.

Maturity—From the information received it is apparent that most farmers desire an early maturing oat variety, as the earliness of Ajax was favourably commented upon by a great many growers. Early maturing varieties can be harvested in many areas before the wheat harvesting commences and in areas subject to fall frosts they are more likely to escape frost damage than the later maturing ones, while in all areas, especially in Western Canada, they are useful as a cleaning crop.

Stem Rust—Stem rust caused considerable damage to the older susceptible varieties in 1943 and in spite of the new race of rust that appeared in considerable proportions for the first time, only 11 farmers observed Ajax to be heavily rusted and in these cases the variety was either sown quite late or rusted in low spots in the field; Vanguard and Anthony were reported to be heavily rusted under similar conditions. Quite a number, however, found light to medium infections of rust on Ajax, while a considerable number observed no rust.

Shattering—As Ajax is a new variety little is known concerning its value as a combine oat; 27 farmers, however, stated that it did not shatter easily, while 9 thought it had a tendency to shatter.

Feed Value of Straw—Eleven farmers commented upon the feed value of Ajax straw; 5 considered it either made good sheaf feed or that the stock liked the straw, while 6 thought the straw to be too coarse.

Suggested Improvements—While a number of growers reported that the kernel of Ajax was heavy and plump, the majority expressed a preference for a larger kernel. Although the majority of the farmers considered Ajax to be superior or at least equal to other varieties in straw strength and yield, it also could be improved in these respects.

SUMMARY

Ajax is from a cross, made in 1930, between Victory and Hajira. It is resistant to the common races of stem rust, moderately resistant to crown rust in the mature plant stage, and has a fairly high degree of resistance to smut and halo-blight. It is an early maturing variety, with good strength of straw and a medium sized white kernel, and appears to be fairly widely adapted to conditions in both Eastern and Western Canada.

Exeter is from a cross, made in 1929, between Victory and Rusota. It is resistant to the common races of stem rust and has considerable resistance to halo-blight, but it is susceptible to other diseases. It is slightly shorter in the straw than Victory and 2 to 3 days earlier, except at Saanichton where over a 3-year period it was 12 days earlier. In Eastern Canada it yielded well in the Maritime Provinces and at Lennoxville, Quebec, while in Western Canada it is better suited to the central and northern regions, particularly in areas where stem rust is likely to occur.

ACKNOWLEDGMENTS

The writer is indebted to the cerealists of the Dominion Experimental Farm Service and to Dr. G. P. McRostie, Professor of Field Husbandry, Ontario Agricultural College, Guelph, for their agronomic data, and to the pathologists of the Dominion Laboratory of Plant Pathology, Winnipeg, for their data on disease reaction.

TABLE 3.—SUMMARY OF AGRONOMIC DATA AND DISEASE REACTIONS OF AJAX, EXETER, AND CERTAIN OTHER VARIETIES IN TESTS CONDUCTED BY THE DOMINION EXPERIMENTAL FARMS AND STATIONS FOR A PERIOD OF FROM ONE TO THREE YEARS IN MARITIME PROVINCES, ONTARIO AND QUEBEC, THE PRAIRIE PROVINCES, AND BRITISH COLUMBIA

Varieties	Maturity	Height	Str. of straw	Wt. per bus.	Wt. per 1000 K	Hull	Stem rust infection	Crown rust infection	Smut infection	Halo-blight infection
	Days	inches	1-10	lb.	gm.	%	%	%	%	%
	MARITIME PROVINCES Average of 3 years at Charlottetown and Fredericton, and 2 years at Nappan									
Ajax	93.6	42.3	9.7	35.9	28.2	—	Trace	17.0	—	—
Exeter	100.4	40.4	9.6	37.2	30.6	—	—	—	—	—
Victory	103.6	42.7	9.2	38.6	33.2	—	—	—	—	—
Vanguard	98.2	41.4	9.6	34.9	29.8	—	0.0	21.0	—	—
Erban	97.7	41.8	9.9	35.0	35.2	—	15.0	25.6	—	—
Roxton	104.6	46.2	9.2	36.4	34.8	—	—	—	—	—

TABLE 3.—SUMMARY OF AGRONOMIC DATA AND DISEASE REACTIONS OF AJAX, EXETER, AND CERTAIN OTHER VARIETIES IN TESTS CONDUCTED BY THE DOMINION EXPERIMENTAL FARMS AND STATIONS FOR A PERIOD OF FROM ONE TO THREE YEARS IN MARITIME PROVINCES, ONTARIO AND QUEBEC, THE PRAIRIE PROVINCES, AND BRITISH COLUMBIA—*concluded*

Varieties	Maturity	Height	Str. of straw	Wt. per bus.	Wt. per 1000 K	Hull	Stem rust infection	Crown rust infection	Smut infection	Halo-blight infection
	Days	inches	1-10	lb.	gm.	%	%	%	%	%
	ONTARIO AND QUEBEC Average of 3 years at Ottawa and 1 year at Lennoxville									
Ajax	83.2	43.2	9.8	34.7	28.4	26.0	0.0	4.0	—	—
Exeter	89.0	39.9	8.9	34.4	29.2	—	0.0	20.0	—	—
Banner	91.9	43.6	7.9	34.4	31.5	26.1	34.2	30.0	—	—
Vanguard	87.0	40.7	9.0	34.4	30.5	24.3	0.0	13.5	—	—
Erban	85.7	42.6	9.2	34.0	32.6	24.1	19.2	5.0	—	—
Roxton	88.8	45.2	7.4	36.8	35.3	20.8	4.5	4.0	—	—
Dasix	84.5	43.3	6.7	34.8	30.8	—	17.8	15.0	—	—
Alaska	80.4	42.7	6.8	36.5	31.1	—	21.8	17.0	—	—
	PRAIRIE PROVINCES Average of 1-2 years at 5 testing points in Manitoba, 1 in Saskatchewan, and 3 in Alberta									
Ajax	99.0	43.8	7.4	37.7	26.9	24.6	2.5	37.2	9.0	2.3
Exeter	105.7	45.2	6.5	37.1	26.9	26.0	0.8	76.7	31.6	4.6
Victory	106.1	47.0	6.7	38.5	28.7	27.3	38.5	80.0	—	17.6
Vanguard	102.4	44.3	7.0	35.8	26.7	23.2	0.8	71.7	49.4	4.4
Erban	102.6	43.8	6.1	36.2	31.0	—	25.8	58.3	0.5	21.7
Roxton	—	—	—	—	—	—	23.3	68.3	15.4	—
	BRITISH COLUMBIA Average of 3 years at Saanichton and 1 year at Agassiz									
Ajax	105.5	39.4	10.0	38.9	28.9	—	—	—	—	—
Exeter	108.6	37.6	10.0	37.9	29.4	—	—	—	—	—
Victory	115.9	41.5	10.0	39.9	31.9	—	—	—	—	—
Erban	104.2	39.9	9.6	39.0	35.4	—	—	—	—	—
Dasix	105.0	41.2	9.9	39.4	30.6	—	—	—	—	—
Roxton	115.7	47.5	10.0	38.6	31.2	—	—	—	—	—

Disease Reactions: Rusts—Maritime Provinces, average of three stations in 1943; Ontario and Quebec average of two years at Ottawa, one year at Lennoxville; Western Canada, average of three years at Winnipeg Smuts, average of loose and covered smut, for two years at Winnipeg. Halo-blight, average of two years at Winnipeg.

TABLE 4.—YIELDS OF AJAX AND EXETER COMPARED WITH OTHER VARIETIES IN TESTS CONDUCTED BY THE DOMINION EXPERIMENTAL FARMS AND STATIONS IN EASTERN AND WESTERN CANADA AND IN CO-OPERATIVE TESTS CONDUCTED IN WESTERN ONTARIO BY THE ONTARIO AGRICULTURAL COLLEGE FOR PERIODS OF FROM ONE TO FOUR YEARS

Stations	No. of years tested	Ajax	Exeter	Victory	Banner	Van-guard	Erban	Gopher	Dasix	Alaska	Roxton
Charlottetown	3	56.0	65.8	60.9	—	60.5	61.7	—	60.4	59.8	60.2
Nappan	2	84.4	87.8	87.7	77.0	74.8	80.0	79.6	—	76.2	81.6
Fredericton	3	78.4	80.9	79.1	—	74.2	74.2	—	80.1	—	75.4
St. Anne de la (a)	3	95.1	—	—	90.2	88.9	91.7	—	—	—	101.0
Pocatiere (b)	3	38.0	—	—	33.4	34.7	36.2	—	—	—	35.0
Lennoxville	2	103.8	109.6	—	99.2	108.4	—	—	—	—	—
L'Assomption	1	80.5	—	—	97.1	89.0	88.7	—	—	—	95.9

TABLE 4.—YIELDS OF AJAX AND EXETER COMPARED WITH OTHER VARIETIES IN TESTS CONDUCTED BY THE DOMINION EXPERIMENTAL FARMS AND STATIONS IN EASTERN AND WESTERN CANADA AND IN CO-OPERATIVE TESTS CONDUCTED IN WESTERN ONTARIO BY THE ONTARIO AGRICULTURAL COLLEGE FOR PERIODS OF FROM ONE TO FOUR YEARS—*concluded*

Stations	No. of years tested	Ajax	Exeter	Victory	Banner	Vanguard	Erban	Gopher	Dasix	Alaska	Roxton
Normandin	3	101.6	—	—	88.6	90.4	87.6	—	—	—	107.1
Makamik	2	53.7	—	—	40.6	—	38.6	—	48.1	—	—
Ont. Agric. Coll.	2	54.2	—	—	—	42.0	42.1	—	47.6	42.9	36.7
Harrow	3	71.3	—	—	—	—	—	—	68.7	69.3	—
Ottawa	3	62.7	51.9	51.1	52.1	53.1	59.8	—	53.9	56.4	55.1
Kapuskasing	3	67.5	—	—	—	—	67.4	—	68.3	57.4	—
Fort William	3	107.1	89.7	—	—	93.0	—	—	—	71.4	—
Winnipeg	4	114.0	101.0	88.2	88.1	97.5	89.6	96.1	—	—	—
Morden	4	97.1	82.6	75.0	—	80.0	—	75.8	—	—	—
Brandon	4	112.2	107.5	105.7	—	100.0	—	101.2	—	—	—
Indian Head	4	84.0	90.5	87.6	—	82.0	—	75.8	—	—	—
Swift Current	2	79.1	81.4	74.8	74.1	80.2	—	73.4	—	—	—
Scott	4	49.4	49.0	43.5	—	43.3	—	44.7	—	—	—
Melfort	4	71.6	82.6	79.0	—	73.2	—	70.8	—	—	—
Lethbridge (c)	1	93.6	87.4	87.2	—	98.0	110.4	—	92.1	—	70.7
(d)	1	96.0	128.1	115.8	—	102.7	82.5	—	—	—	80.3
Lacombe	2	118.0	121.4	118.6	—	104.2	93.4	—	117.6	—	—
Beaverlodge	3	75.1	86.2	89.2	87.1	—	—	—	—	—	—
Fort Vermilion	1	95.2	95.6	106.1	—	91.5	91.7	90.5	—	—	—
Agassiz	1	52.9	58.1	58.7	—	—	58.1	52.3	52.8	52.5	59.9
Smithers	1	83.9	—	101.6	—	92.3	89.8	87.3	98.1	—	—
Prince George	1	52.3	58.4	54.4	—	52.7	44.9	46.7	54.5	—	61.2
Saanichton	3	65.3	56.5	60.1	—	—	65.4	—	67.4	—	54.8

NOTE.—a = clay land, b = sandy land; c = dry land, d = irrigated land.

TABLE 5.—SUMMARY OF DATA IN QUESTIONNAIRES RETURNED BY 1,050 FARMERS GROWING AJAX IN 1943

Area	No. of questionnaires returned	Suitability for area expressed in percentage of questionnaires returned			Strength of straw in comparison with other varieties expressed in percentage of questionnaires returned			Yield of Ajax in comparison with other varieties grown under similar conditions		
		Suited	Undecided	Not suited	Stronger	Similar	Weaker	No. of farms	Ajax	Other varieties
	MANITOBA									
Northern	64	95.3	4.7	0	59.3	30.5	10.2	—	—	—
Central	314	84.8	11.9	3.3	64.8	24.5	10.7	6	58.8	39.7
Southern	112	88.0	12.0	0	68.3	11.9	19.8	4	62.8	46.2
Totals and Averages	490	86.9	11.0	2.1	64.9	22.4	12.7	10	60.4	42.3

TABLE 5.—SUMMARY OF DATA IN QUESTIONNAIRES RETURNED BY 1,050 FARMERS GROWING AJAX IN 1943—*concluded*

Area	No. of question-naires returned	Suitability for area expressed in percentage of questionnaires returned			Strength of straw in comparison with other varieties expressed in percentage of questionnaires returned			Yield of Ajax in comparison with other varieties grown under similar conditions		
		Suited	Un-decided	Not suited	Stron-ger	Similar	Weaker	No. of farms	Ajax	Other varieties
	SASKATCHEWAN									
Northern	124	78.7	18.0	3.3	60.2	29.6	10.2	7	67.2	52.9
Central	199	73.3	23.1	3.6	59.8	33.5	6.7	8	60.9	60.2
Southern	101	82.7	17.4	0	59.1	53.3	7.5	9	65.7	54.4
Totals and Averages	425	77.1	20.2	2.7	59.7	32.3	7.9	24	64.5	55.9
	ALBERTA									
Peace River	18	70.6	23.5	5.9	50.0	43.8	6.2	—	—	—
North Central	32	73.4	13.3	13.3	55.2	27.6	17.2	2	72.5	63.0
Central	49	86.7	11.1	2.2	60.5	31.6	7.9	2	45.0	37.5
Southern	15	71.4	7.2	21.4	62.5	25.0	12.5	—	—	—
Totals and Averages	114	78.3	13.2	8.5	57.2	31.9	11.0	4	58.7	50.2
	WESTERN ONTARIO									
Totals and Averages	21	85.7	14.3	0.0	52.6	36.8	10.6	15	48	42

AGRONOMIC AND QUALITY CHARACTERISTICS OF CARLETON DURUM WHEAT GROWN IN THE DURUM WHEAT AREA OF WESTERN CANADA[1]

R. F. PETERSON[2] AND W. O. S. MEREDITH[3]

Ever since durum wheat became established as a recognized commercial crop in Canada, Mindum has been the leading variety. It has set the standard of quality for durum wheats just as Marquis has done for hard red spring wheats. Mindum has also been outstanding agronomically, but has not had sufficient straw strength for all conditions and, being only moderately resistant to stem rust, has suffered some loss in yield and grade in rust years.

The new variety, Carleton, was developed by the North Dakota Agricultural Experiment Station in co-operation with the Division of Cereal Crops and Diseases, U.S. Department of Agriculture. When grown in the durum wheat area of the United States, it proved to have stronger straw and more stem rust resistance than Mindum and seed of it was distributed to seed growers in that area in 1943.

Seed of Carleton for field tests in Canada was received by the Dominion Laboratory of Cereal Breeding, Winnipeg, in 1941.

The origin of Carleton is described by Smith (1). The original cross, Vernal Emmer × Mindum, was made in 1930 and many rust resistant strains were obtained but none had the good macaroni-making quality of Mindum. Selected strains were back-crossed with Mindum in 1933, and, after further selection, a second back-cross was made with Mindum in 1936. Carleton is a derivative of this second back-cross.

Smith (1) and Stoa (2) have outlined the characteristics of Carleton wheat. As compared to Mindum, Carleton is described as having more resistance to stem rust; stronger, coarser straw; more erect heads; shorter, plumper kernels; slightly later maturity; and equal semolina quality. Carleton has usually yielded as much as or more than Mindum under rust conditions and slightly less than that variety in non-rust years. In the northern part of North Dakota, adjacent to the durum-growing area of Canada, the yields of the two varieties have been similar although farther south Carleton has yielded relatively less.

The present paper is concerned with a comparison of the performances of Mindum and Carleton wheats in the durum wheat area of Western Canada.

FIELD TESTS

Co-operative rod-row tests of various durum wheats including Mindum and Carleton have been conducted during the years 1941, 1942 and 1943 at the Dominion Laboratory of Cereal Breeding, Winnipeg, and on Dominion Experimental Farms and Stations in the durum wheat area of Western Canada. Each year a uniform set of 16 varieties was tested in balanced lattice field tests. Such a test is comprised of 5 complete blocks

[1] Joint contribution from the Cereal Division, Experimental Farms Service, Dominion Department of Agriculture, and the Grain Research Laboratory, Board of Grain Commissioners for Canada, Winnipeg. Published as Paper No. 130 of the Cereal Division, as Grain Research Laboratory No. 71, and as Paper No. 233 of the Associate Committee on Grain Research. Read before the Western Canadian Society of Agronomy at Saskatoon, Sask., June 22 and 23, 1944.
[2] Senior Assistant Agricultural Scientist, Dominion Laboratory of Cereal Breeding, Winnipeg, Manitoba.
[3] Chemist, Grain Research Laboratory, Board of Grain Commissioners for Canada, Winnipeg.

each containing all 16 varieties and being subdivided into 4 incomplete blocks each consisting of 4 varieties. Each plot consisted of 4 rod-rows sown 9 inches apart, the two centre rows being used for yield determinations. Seed for similar field tests was sent to the North Dakota Agricultural Experiment Station and the tests were conducted at the sub-station at Langdon. All yield data were subjected to an analysis of variance.

One exception to the above plan should be noted. The test at Winnipeg in 1943 was damaged by heavy rains flooding it in early summer, and two complete blocks had to be discarded. The remaining three blocks were treated in analysis as a randomized block test. The variation due to water damage, and the small number of replications resulted in a high experimental error for yield.

Stem rust and leaf rust epidemics were artificially induced at Winnipeg but not at the other Canadian stations.

AGRONOMIC CHARACTERISTICS

The results of the co-operative rod-row tests and of special tests are given in summary form in Tables 1 and 2.

Yield

In interpreting the data in Table 1, it should be kept in mind that the yields are, on the whole, considerably higher than average farm yields and that the varietal and minimum significant differences are correspondingly augmented.

Of the 16 yield tests conducted in Canada, all but one (Indian Head, 1941) showed statistically significant differences between varietal mean yields, but only one (Indian Head, 1943) gave a significant difference between Mindum and Carleton, the difference being in favour of Mindum. As the 5% level of significance was used, such an occurrence of one statistically significant difference in 16 comparisons of two varieties might easily be expected if the two varieties were actually of equal yielding ability. It is of interest that considering all 16 differences, however small, Carleton led in yield in 9 tests and Mindum in 7.

An examination of annual and station averages in Table 1 shows Mindum leading in two of the three years and at four of the six Canadian stations, and being 0.6 bushel above Carleton in the three-year average. Under average farm conditions this difference in terms of a fraction of a bushel would probably be reduced both because of lower yields as compared to experimental yields and because a portion of lodged grain harvested by farm machinery may be lost, whereas in the experimental field tests, although Mindum lodged more than Carleton, care was taken to recover all the grain from each plot.

The yield results obtained in the three years of the tests do not appear to establish either of the two named varieties as being superior to the other in yield under the conditions of the tests.

Maturity

Carleton was about a day later in maturing than Mindum. As this difference was due mainly to tests in Manitoba, where most of the rust

occurred, it is possible that the slightly earlier maturity of Mindum was caused, at least in part, by rust.

Straw

The straw of Carleton is definitely stronger and somewhat coarser than that of Mindum. This is true of the "neck" as well as the lower parts of the stem so that the head is erect, rather than nodding as in Mindum.

Height

Carleton averaged slightly taller than Mindum. This again was due to the Manitoba tests, as Mindum averaged slightly taller than Carleton in the Saskatchewan tests. It seems probable that the shortness of straw of Mindum in Manitoba was due to rust damage.

Head Type

Carleton has a head similar to that of Mindum with reddish brown glumes and awns but the awns fall off more readily.

Kernel Type

The kernel of Carleton is shorter, plumper, and somewhat heavier than that of Mindum, with a clear amber colour. The grain sample has a good appearance.

Stem Rust

Under the conditions of the tests Carleton was more resistant than Mindum to stem rust. The average stem rust reaction of Mindum for the three years, however, was quite low and would have been lower had the natural epidemic at Winnipeg not been supplemented with an artificially-induced one.

Leaf Rust

Carleton and Mindum are both highly resistant to leaf rust. Carleton has less resistance than Mindum, but the difference appears to be of no practical importance as it has been evident only under severe artificially-induced leaf rust epidemics.

Bunt

Both varieties appear to be moderately susceptible. It was not possible to determine from this one test whether or not there is a real difference between the two varieties.

Root Rot

Both Carleton and Mindum were more resistant than most of the other varieties tested. The slight difference between the two was not statistically significant.

Kernel Smudge

Carleton has been consistently more susceptible than Mindum to kernel smudge at the various stations.

QUALITY

The macaroni-making qualities of Carleton have been compared with those of Mindum, the standard of quality for durum wheats, by means of laboratory tests on comparable samples of each variety grown in Western Canada in each of the years 1941, 1942, and 1943. These tests were made on samples obtained by compositing the grain from the several stations at which the varieties were grown in the Co-operative Test of Durum Wheat Varities that is conducted annually under the direction of the Dominion Laboratory of Cereal Breeding, Winnipeg. In addition, semi-commercial and commercial tests were made on samples of each variety grown in Manitoba in 1943. These were composite samples representing grain grown at four points.

The results of the laboratory tests, which were made in the Grain Research Laboratory, Board of Grain Commissioners for Canada, Winnipeg, are quite clear cut, as is shown in Table 3. The two varieties are similar in grade, protein content, ash and pigment content of the wheat, although Carleton tends to be somewhat higher than Mindum in bushel weight and 1,000 kernel weight. Similarities between the varieties in semolina characteristics are also evident, though Carleton tends to be somewhat higher in semolina pigment content, which is an advantage. The best comparison between varieties is, however, the rating of the macaroni. Macaroni quality is judged by appearance; a bright, clear, yellow colour is desirable. In this laboratory, colour determinations are also made on macaroni, and the results for percentage yellow are closely related to the visual placing of the samples. Carleton was rated higher than Mindum in each of the 3 years, as is shown by the visual placing results in Table 3 and confirmed by the values for yellow colour and brightness. It is thus apparent that the higher "kernel smudge" infection of Carleton, as compared with Mindum, which was mentioned in the previous section, did not influence the colour of either semolina or macaroni.

The samples prepared for the commercial tests were tested in the laboratories of General Mills Inc., Minneapolis, and of the Board of Grain Commissioners for Canada; in the semi-commercial scale plant of Pillsbury Flour Mills Co., Minneapolis; and under commercial conditions in the Winnipeg Plant of the Catelli Food Products Ltd. In all these tests Carleton was found to be equal or superior to Mindum in appearance of macaroni. Cooking tests have been made by many individuals on the samples prepared commercially and the consensus of opinion is that Carleton produced somewhat brighter macaroni and that the two varieties do not differ with respect to taste of the cooked macaroni.

There is thus ample evidence to indicate that Carleton grown in Western Canada is at least equal, if not slightly superior, to Mindum in macaroni-making quality. These results agree with those obtained in the United States, where tests have been made on Carleton and Mindum for

several years. Carleton has been found to be equal to or slightly better than Mindum in quality when tested in the durum-wheat growing area of the United States.

SUMMARY AND CONCLUSIONS

Field tests of durum wheat varieties including the new variety, Carleton, and the standard variety, Mindum, were conducted in the durum wheat area of Western Canada at 5 stations in 1941 and 1942, and at 6 stations in 1943, making a total of 16 tests. Carleton gave the higher average yield in 9 tests and Mindum in 7, but in only one case was the difference statistically significant, Mindum having the higher yield.

Comparative data were obtained on days to ripen, strength of straw, height, kernel characteristics, stem rust, leaf rust, bunt, root rot, kernel smudge, and on various factors contributing to macaroni-making quality.

Carleton was distinctly superior to Mindum in strength of straw and in resistance to stem rust, the two characteristics in which improvement has been most needed, but was somewhat more susceptible to kernel smudge. Other differences occurred which however did not appear to be of much practical importance.

The macaroni-making quality of Carleton appeared to be equal if not slightly superior to that of Mindum.

It seems probable that Carleton will be a useful variety in some parts of the durum wheat area of Western Canada particularly in Manitoba where stem rust damage and lodging are more severe on the average than in Saskatchewan. More comprehensive testing and observations on representative farms will be necessary before the adaptation of Carleton to definite zones can be determined.

ACKNOWLEDGMENTS

The writers are indebted to the cerealists at the Dominion Experimental Farms and Stations at Brandon, Morden, Melita, Indian Head and Swift Current for supplying data from their field tests.

Thanks are extended to the members of the Dominion Laboratory of Plant Pathology, Winnipeg, previously mentioned in connection with Table 2, for providing data on disease reactions.

The co-operation of Mr. E. V. Hetherington, General Mills Inc., Minneapolis, Minn.; Mr. R. N. McCaull, Pillsbury Flour Mills Company, Minneapolis, Minn.; and Mr. A. Robitaille and Mr. R. Sampson, Catelli Food Products Ltd., Winnipeg, and Montreal, in making quality tests, is gratefully acknowledged.

REFERENCES

1. Smith, Glenn S. Two new durum wheat varieties. Bimonthly Bulletin, North Dakota Agricultural Experiment Station, 5 : 4; 2-3. 1943.
2. Stoa, T. E. Seed of new rust resistant durums available. Bimonthly Bulletin, North Dakota Agricultural Experiment Station, 6 : 2; 5-6. 1943.

TABLE 1.—YIELD IN BUSHELS PER ACRE OF MINDUM AND CARLETON DURUM WHEATS IN CO-OPERATIVE ROD-ROW TESTS IN THE YEARS 1941-1943, INCLUSIVE

Crop year	Variety	Manitoba				Saskatchewan		North Dakota	Mean all stations	Mean Canadian stations
		Winnipeg	Morden	Brandon	Melita	Indian Head	Swift Current	Langdon		
1941	Mindum	36.0	33.3	40.1	—	33.2	3.6	13.2	26.6	29.2
	Carleton	35.6	35.3	40.7	—	37.4	4.0	24.8	29.6	30.6
		(5.1)*	(6.2)	(3.6)	—	(†)	(1.8)	(2.9)	—	—
1942	Mindum	30.8	73.1	63.7	—	61.0	43.5	40.8	52.2	54.5
	Carleton	35.3	65.2	67.3	—	58.5	41.4	42.0	51.6	53.5
		(7.3)	(6.7)	(6.3)	—	(7.2)	(5.8)	(7.6)	—	—
1943	Mindum	30.9	37.7	40.8	37.3	39.1	14.3	39.7	34.2	33.5
	Carleton	25.0	34.3	41.9	38.8	34.8	14.4	33.8	31.8	31.5
		(14.0)	(4.5)	(8.2)	(7.3)	(2.1)	(7.8)	(5.1)	—	—
Three-year average	Mindum	32.6	48.0	48.2	—	44.4	20.5	31.2	37.7	39.1
	Carleton	32.0	44.9	50.0	—	43.6	19.9	33.5	37.7	38.5

* Figures in brackets indicate minimum significant differences between varietal means at the 5% level of significance.

† Varietal differences not significant, hence no minimum significant difference.

TABLE 2.—AVERAGE AGRONOMIC DATA FROM THE VARIOUS STATIONS IN WESTERN CANADA

Crop year	Variety	Co-operative rod-row tests						Special tests*		
		Days to ripen	Strength of straw 0-10	Height in inches	Stem rust		Kernel smudge† %	Leaf rust %	Bunt %	Root rot %
					A‡ %	B‡ %				
1941	Mindum	96.8	7.6	38.0	26.0	4.6	—	4	—	—
	Carleton	98.1	7.9	39.3	1.0	0.2	—	15	—	—
1942	Mindum	113.8	4.9	49.8	35.0	7.2	6.4	trace	—	—
	Carleton	114.6	6.6	49.4	0.4	0.1	9.7	15	—	—
1943	Mindum	112.4	5.4	42.0	3.4	0.6	5.8	0	35	6.4
	Carleton	112.8	7.1	43.2	0.0	0.0	8.6	0	47	5.4
Three-year average	Mindum	107.7	6.0	43.3	21.5	4.1	—	2	—	—
	Carleton	108.5	7.2	44.0	0.5	0.1	—	10	—	—

* Data provided by members of the Dominion Laboratory of Plant Pathology, Winnipeg, as follows:
Leaf Rust, 1941 and 1942: Margaret Newton and B. Peturson.
Bunt: W. Popp.
Root Rot: F. J. Greaney.

† Kernel smudge percentages based on all stations in 1942 and 1943. Data provided by H. A. H. Wallace of the Dominion Laboratory of Plant Pathology, Winnipeg.

‡ A: Stem rust readings from the station having the most rust in a given year. (Winnipeg, 1941 and 1942; Morden, 1943).
B: Average reading for all stations.

TABLE 3.—DATA FOR WHEAT, SEMOLINA, AND MACARONI, SHOWING COMPARISON OF MINDUM AND CARLETON

Crop year	Variety	Wheat					
		Grade	Bushel weight	1,000 Kernel wt.	Protein	Ash	Pigment content
			lb.	g	%	%	p.p.m.
1941	Mindum	2 C.W.	65.0	37.1	15.7	1.59	5.95
	Carleton	2 C.W.	66.9	42.6	15.7	1.60	5.60
1942	Mindum	3 C.W.	65.4	41.9	13.1	1.59	6.15
	Carleton	2 C.W.	67.0	43.7	13.4	1.59	6.10
1943	Mindum	2 C.W.	67.0	40.9	14.2	1.55	4.70
	Carleton	2 C.W.	67.0	41.6	14.3	1.54	5.10

Crop year	Variety	Semolina			
		Yield	Protein	Ash	Pigment
		%	%	%	p.p.m.
1941	Mindum	54.0	14.7	0.64	4.90
	Carleton	55.5	14.7	0.59	4.90
1942	Mindum	53.4	12.4	0.59	4.55
	Carleton	55.5	12.2	0.54	4.90
1943	Mindum	53.8	13.1	0.53	4.25
	Carleton	51.0	13.1	0.51	4.95

Crop year	Variety	Macaroni					
		Pigment	Colour quality			Brightness	Visual placing
			Yellow	Red	White		
		p.p.m.	%	%	%	%	
1941	Mindum	—	50.9	22.8	26.3	57.0	2
	Carleton	—	49.6	22.3	28.1	60.5	1
1942	Mindum	3.50	44.5	20.3	35.2	64.0	2
	Carleton	3.65	52.1	18.5	29.4	73.0	1
1943	Mindum	2.70	55.4	21.8	22.8	50.5	2
	Carleton	3.05	54.4	24.6	21.0	57.0	1